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BATTLE CREEK AREA CLEAN WATER PARTNERS

Stormwater Management Program:

Technical Reference Manual

December

2012

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Stormwater Management Technical

Reference Manual (TRM)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Appendix

BATTLE CREEK AREA CLEAN WATER PARTNERS

STORMWATER MANAGEMENT TECHNICAL REFERENCE MANUAL (TRM)

1.0 INTRODUCTION

1.1 Overview

The Battle Creek Area Clean Water Partners (BCACWP) are comprised of the City of Battle Creek, the City of Springfield, Calhoun County Road Department, the Calhoun County Water Resources Commissioner, the townships of Bedford, Emmett, Leroy, Newton, and Pennfield, and Battle Creek Area Schools. They have joining together with the common goal of protecting surface water and groundwater in the Greater Battle Creek area and have developed a Stormwater Management Technical Reference Manual (TRM). The purpose of the manual is to preserve pre-development ground water and surface water drainage patterns and to preserve water quality within the area by limiting pollutants and Stormwater volume.

The Stormwater systems in the Greater Battle Creek area are separate from the sanitary system owned and operated by the City of Battle Creek. Stormwater discharges directly to a river, a lake, a wetland, or to groundwater without being cleaned or treated. Stormwater, which is from rainfall and snowmelt, picks up pollutants and contaminants as it flows over impervious surfaces and into the storm sewer system. Stormwater is one form of non-point source pollution. The United States Environmental Protection Agency (USEPA) considers non-point source pollution to be the nation's largest threat to water quality.

This manual emphasizes Green Infrastructure techniques, combined with conventional Stormwater retention and detention basins. The use of Green Infrastructure finds a balance between new and re-development while limiting the impact on the environment. The use of Green Infrastructure helps to maintain the natural hydrology of a site to retain its pre-development conditions, such as its infiltration, evaporation, and runoff rates.

Green Infrastructure can be accomplished through the development and implementation of Stormwater control measures (SCM), such as wet swales, catch basins, green roofs, and rain gardens, to name a few. SCMs can be implemented to reduce Stormwater runoff, help with pollutant removal, and reduce erosive stream velocities. These techniques are commonly utilized throughout the United States and often their use is more cost effective than conventional systems.

For additional information about Green Infrastructure, consult the Low Impact Development Manual for Michigan. The manual can be obtained at www.semcog.org/

1.2 Flow Chart

The attached flow chart presented in Figure 1.1–1 provides a step-by-step summary of how to evaluate drainage systems for site-developed projects. The flow chart identifies fifteen steps as listed below:

1.2.1 Compile Project Data.

This step must comply with the Site Plan Ordinance requirements of the reviewing agency. The basic components of this data include the following:
Proposed Land Use
Topography
Soils
Pre and Post hydrology study
Proposed drainage
Water Quality BMPs/Green Infrastructure techniques highlighted
Existing drainage
Existing downstream facilities

In general, project data should cover contributing drainage areas; or if adjacent property does not contribute, a minimum of 100 feet beyond project borders. Also, determine if property is located in a wellhead protection area. See the Appendix for the stormwater checklist and wellhead protection area locations.

1.2.2 Is complete onsite retention (no discharge offsite) being provided?

This is the first in a series of questions to assign the project into one of two basic categories. The first is for drainage systems without a positive outlet and the second with such an outlet. If the answer to this question is yes, limiting factors for infiltration will need to be determined, such as poor soils or depth to the water table. Poor soils are classified with an infiltration rate (saturated hydraulic conductivity rate) of less than 0.52 inches per hour. If no limiting factors exist, proceed along the path. If limiting factors exist or if no complete onsite retention is being provided, proceed to Step 3. For additional guidance, refer to the Michigan Department of Environmental Quality, Stormwater Management Guidebook http://www.deq.state.mi.us/documents/deq-lwm-nfip-SMGMastr.pdf.

1.2.3 Is there an outlet for site drainage?

A positive outlet allows the project to proceed toward Step 11. If the answer is no, the project is approved by unique design only. If the answer is yes, proceed to Step 4.

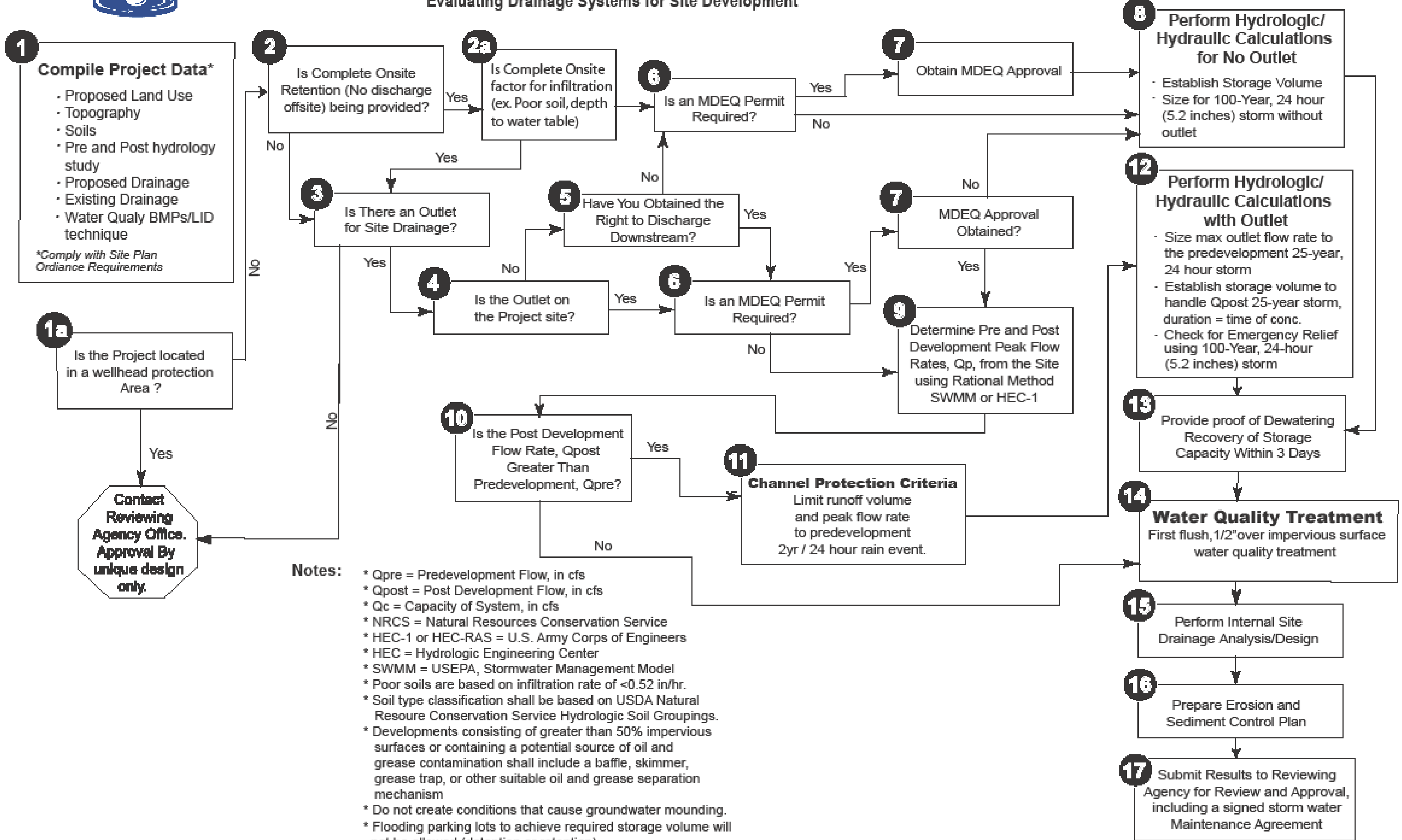
1.2.4 Is the outlet on the project site?

If the answer is no, proceed to Step 5. If the answer is yes, proceed to Step 6.

Battle Creek Area Clean Water Partners

Figure 1-1

Stormwater Management Program Procedure
Evaluating Drainage Systems for Site Development



Notes:

* Qpre = Predevelopment Flow, in cfs
* Qpost = Post Development Flow, in cfs
* Qc = Capacity of System, in cfs
* NRCS = Natural Resources Conservation Service
* HEC-1 or HEC-RAS = U.S. Army Corps of Engineers
* HEC = Hydrologic Engineering Center
* SWMM = USEPA, Stormwater Management Model
* Poor soils are based on infiltration rate of <0.52 in/hr.
* Soil type classification shall be based on USDA Natural Resource Conservation Service Hydrologic Soil Groupings.
* Developments consisting of greater than 50% impervious surfaces or containing a potential source of oil and grease contamination shall include a baffle, skimmer, grease trap, or other suitable oil and grease separation mechanism
* Do not create conditions that cause groundwater mounding.
* Flooding parking lots to achieve required storage volume will not be allowed (detention or retention)

1.2.5 Have you obtained the right to discharge downstream?

To obtain this right, a drainage easement or right-of-way must be established as a legally binding constraint on the appropriate downstream property. In addition, the reviewing agency will require a Drainage Acceptance Covenant (a standard form is provided in the Appendix), from the owner of the downstream property. This form indicates full knowledge of the proposed alteration in pre-existing drainage patterns and accepts responsibility to indemnify, defend and save harmless the Reviewing Agency from all liability due to the proposed alteration. If the answer to this question is no, the project is redirected back towards Step 8 for the condition when no outlet exists. If the answer is yes, proceed towards Step 11. In both cases, the next step is Step 6.

1.2.6 Is an MDEQ permit required?

The site developer is responsible to determine if state regulations regarding inland lakes and streams or wetlands will require that a permit be obtained from the Michigan Department of Environmental Quality (MDEQ). In both cases, if a permit is required, proceed to Step 7. If a permit is not required, proceed to Step 8, when no outlet is available and Step 9 when an outlet is available. If MDEQ approval is not obtained for the positive outlet option, the project must proceed to Step 8, the no outlet condition.

1.2.7 Obtain MDEQ Approval.

Approval for MDEQ is the responsibility of the applicant.

1.2.8 Perform hydrologic/hydraulic calculations for no outlet conditions.

For this case, complete retention of post development runoff for the 100-year, 24 hour storm event (5.2 inches) is required. No reduction in the required storage volume for infiltration during the storm is allowed. Certain soil conditions may allow for such a reduction in volume only if additional soils investigation is done and if LID or Green Infrastructure design is proposed. The amount of required volume reduction is dependent upon the proposed design being able to handle the 100-year, 24 hour event as well as shorter duration events that create peak flow rates. This will be considered on a case by case basis.

1.2.9 Determine pre- and post- development peak flow rates.

Procedures to develop pre- and post-development peak flow rates are presented in Chapter 5.0 of the manual. Pre-development conditions are intended to represent natural land cover; however, current land cover conditions can be used where upstream tributary areas have been developed.

1.2.10 Is the post-development peak flow rate greater than pre-development?

The Battle Creek Area Clean Water Partners requires that post-development peak flow rates cannot exceed pre-development peak flow rates. If they do, detention storage and calculations as presented in Step 11 must be performed. If the pre-development peak flow rate is not exceeded, proceed to Step 13. The comparison of a typical pre-and post-development hydrograph is provided in Figure 1.1-2. This figure shows the difference in shapes and identifies the additional volume of runoff generated under post-development conditions.

1.2.11 Determine the CHANNEL PROTECTION criteria.

Channel protection criteria is necessary to maintain post-development site runoff volume and peak flow rate at or below existing levels for all storms up to the 2-year, 24-hour event. "Existing levels" means the runoff flow volume and rate for the last land use prior to the planned new development or redevelopment. Where more restrictive channel protection criteria already exists or is needed to meet the goals of reducing runoff volume and peak flows to less than existing levels on lands being developed or redeveloped, the use of more restrictive criteria may be required.

1.2.12 Perform hydrologic/hydraulic calculations for FLOOD CONTROL

For storms exceeding the 2-year, 24-hour event, an outlet structure must restrict the peak discharge rate for the 25 year storm whose duration equals the peak time of concentration. Adequate storage volume to achieve this peak flow reduction is required on the development site. The overland emergency flow relief path must be identified and designed for the 100-year, 24-hour design storm.

1.2.13 Provide proof of dewatering recovery of storage capacity within 3 days.

If no positive outlet is available to dewater storage within 3 days, an evaluation of the natural soil saturated infiltration rate is required to verify that the storage volume can be recovered within 3 days. If the natural soil saturated infiltration rate is inadequate, consult the proper reviewing agency.

1.2.14 Determine WATER QUALITY TREATMENT criteria.

Figure 1.1-3 shows the effects on water quality as the percentage of areas with impervious cover increases due to development. A main focus of this TRM is the use of low impact development techniques, which will help minimize impervious areas and will help protect water quality.

1.2.15 Perform internal site drainage analysis/design.

Project specific drainage analysis and design evaluations must be performed. Flooding parking lots to achieve required storage volume will not be allowed for either retention or detention.

1.2.16 Prepare Erosion and Sediment Control Plan and obtain permit.

All sites within 500 feet of a lake, stream, or county drain; or disturbance of more than one acre of land, must have a Soil Erosion Sedimentation Control (SESC) permit prior to obtaining a building permit. An erosion and sediment control plan is required to obtain an SESC permit. The Calhoun County Road Department, located at 13300 Fifteen Mile Road, Marshall, Michigan, administers the SESC program for Calhoun County.

1.2.17 Submit results to the approval agency for review and approval.

Results of the evaluations and design performed as outlined in the flow chart of Figure 1.1-1 should be compiled in a report and submitted to the reviewing agency for review and approval. A standard checklist form to be used by the Battle Creek Area Clean Water Partners when reviewing drainage and Stormwater management features of site development projects is provided at the end of this section. If everything identified on this checklist is provided and determined to be in compliance with requirements, the project can be approved. If items are found to be missing, or are not in compliance with requirements, this form will be sent to the applicant to indicate the reason or reasons for disapproval.

Performance of Stormwater control measures (SCMs) is dependent on their maintenance. A signed maintenance agreement may be required; check with the appropriate Reviewing Agency. A standard form is provided in the Appendix.

2.0 DESIGN CRITERIA

2.1 Introduction

The purpose of this Section is to provide hydrologic analysis and computational procedures for use in determining Stormwater management requirements and Green Infrastructure strategies. A more detailed reference about the utilization of Green Infrastructure can be found in the Low Impact Development Manual for Michigan at www.semcog.org/

2.2 Hydrologic Comparison Between Conventional and Green Infrastructure Approaches

Figures 2.1 & 2.2 graphically show conventional systems without BMPs, with conventional BMPs, and with Green Infrastructure techniques. Conventional Stormwater conveyance systems are designed to collect, convey, and discharge runoff as efficiently as possible. Conventional Stormwater management BMPs are typically sited at the most downstream point of the entire site (end-of-pipe control).

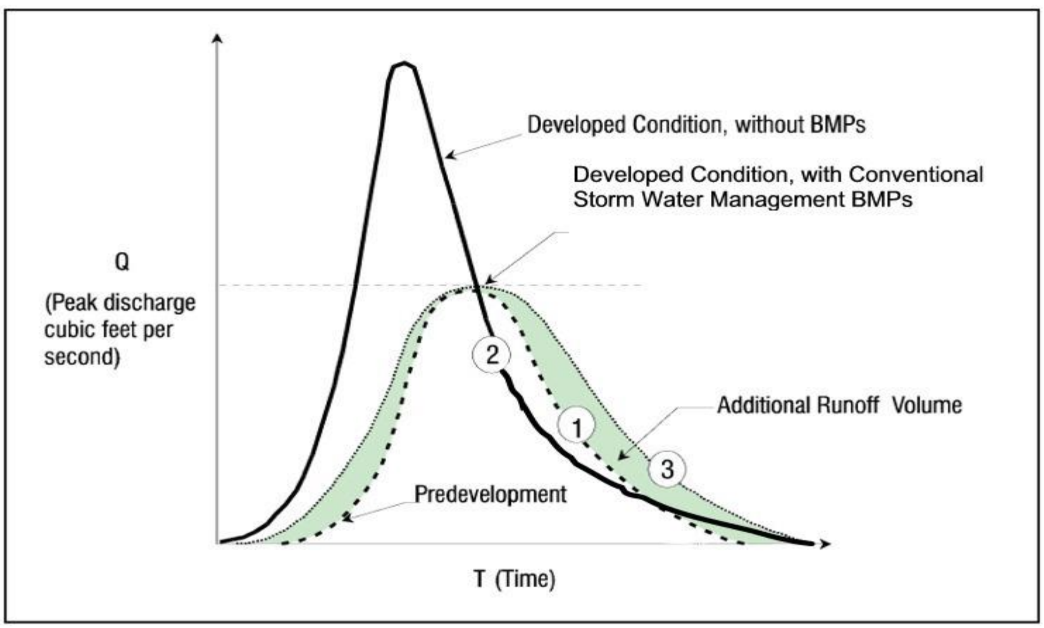


Figure 2.1. Hydrologic Response of Conventional BMPs

- Hydrograph 1 represents a pre-development condition (e.g., woods, meadow), of a site during a storm event. The hydrograph is defined by a gradual rise and fall of the peak discharge and volume.

- Hydrograph 2 represents the response of a post-development condition with no Stormwater management BMPs. This hydrograph definition reflects a shorter time of concentration (Tc) and higher runoff coefficient (C) than that of the pre-development condition, a rapid decrease in the time to reach the peak runoff rate, a significant increase in the peak runoff discharge rate and volume, and increased duration of the discharge volume.
- Hydrograph 3 represents a post-development condition with conventional Stormwater BMPs, such as a detention pond. Although the peak runoff rate is the same, the hydrograph exhibits significant increases in the runoff volume and duration of runoff from the pre-development condition.

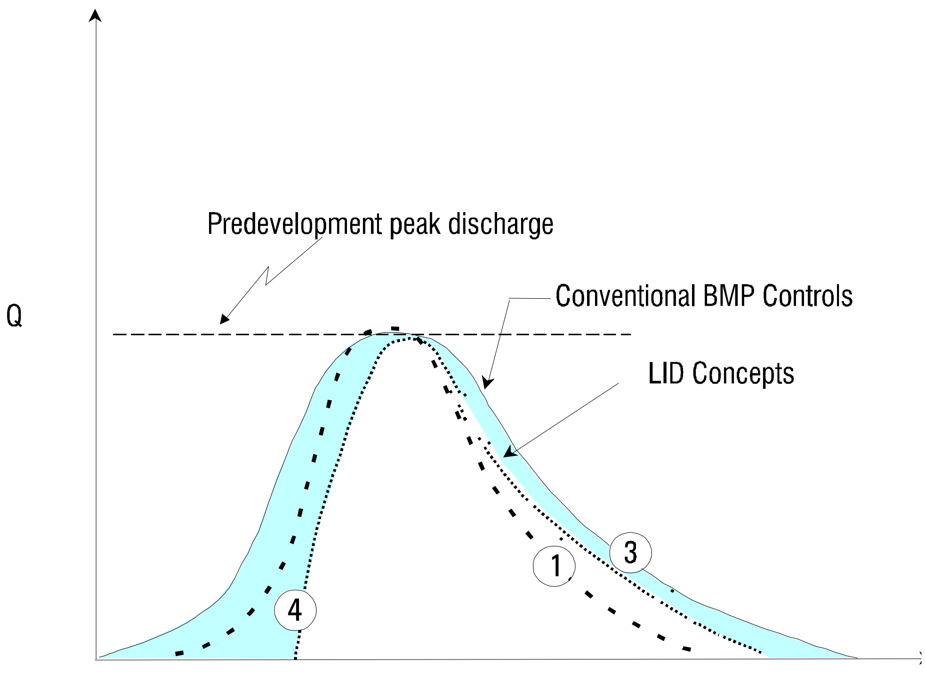


Figure 2.2. Comparison of the Hydrologic Response of Conventional and LID

- For hydrograph 1, refer to Figure 2.1 for description.
- For hydrograph 3, refer to Figure 2.1 for description.
- Hydrograph 4 represents the response of a post-development condition that incorporates Green Infrastructure Stormwater management. Green Infrastructure uses undisturbed areas and smaller retention storage areas distributed throughout the site (on-lot or in common areas) to reduce runoff volume. The peak runoff rate and volume remain the same as the pre-development condition through the use of common area or on-lot retention and/or detention. The frequency and duration of the runoff are also much closer to the existing condition than those typical of conventional BMPs.

In Green Infrastructure, the design approach is to leave as many undisturbed areas as practicable to reduce runoff volume and runoff rates by maximizing infiltration capacity. Stormwater management BMPs are then integrated throughout the site to compensate for the hydrologic alterations of development. The approach of maintaining areas of high infiltration and low runoff potential in combination with small, source control Stormwater management BMPs creates a “hydrologically functional landscape.” This functional landscape not only helps maintain the pre-development hydrologic regime but also enhances the aesthetic and habitat value of the site. Figure 2.2 illustrates a comparison of Green Infrastructure and conventional BMPs.

2.3 Key Green Infrastructure Hydrologic Definitions

The Green Infrastructure "functional landscape" emulates the pre-development temporary storage (detention) and infiltration (retention) functions of the site. This functional landscape is designed to mimic the pre-development hydrologic conditions through runoff volume control, peak runoff rate control, flow frequency/duration control, and water quality control.

- ***Runoff Volume Control*:** The pre-development volume is maintained by a combination of minimizing the site disturbance from the pre-development to the post-development condition and then providing distributed retention BMPs. Retention BMPs are structures that retain the runoff for the design storm event. A "customized" or detailed C evaluation is required to determine the required runoff volume. The storage required to maintain the pre-development volume may also be sufficient to maintain the pre-development peak rate.
- ***Peak Runoff Rate Control*:** Green Infrastructure is designed to maintain the pre-development peak runoff discharge rate for the selected design storm events. This is done by maintaining the pre-development Tc and then using retention and/or detention BMPs (e.g., rain gardens, open drainage BMPs, etc.) that are distributed throughout the site. The goal is to first use retention practices to control runoff volume and, if these retention practices are not sufficient to control the peak runoff rate, to then use additional detention practices to control the peak runoff rate. Detention is temporary storage that releases excess runoff at a controlled rate. The use of a combination of retention and detention to control the peak runoff rate is defined as the hybrid approach. The first half-inch of rainfall must be treated by BMPs for water quality.
- ***Flow Frequency/Duration Control*:** Since Green Infrastructure is designed to emulate the pre-development hydrologic regime through volume and peak runoff rate controls, the flow frequency and duration for the post-development conditions will be almost identical to those for the pre-development conditions (see Figure 2.2). Thus, the impacts on the sediment and erosion and stream habitat potential at downstream reaches can then be minimized.
- ***Water Quality Control:*** Green Infrastructure is designed to provide water quality treatment of runoff from the first 1/2 inch of rainfall using retention practices. Green Infrastructure also provides pollution prevention by modifying human activities to reduce the introduction of pollutants into the environment. Green Infrastructure practices also aid in cooling runoff from developed sites thus lessening thermal peaks in receiving streams.
- ***Channel Protection Criteria:*** Channel protection criteria is necessary to maintain post-development site runoff volume and peak flow rate at or below existing levels for all storms up to the 2-year, 24-hour event. "Existing levels" means the runoff flow volume and rate for the last land use prior to the planned new development or redevelopment. Where more restrictive channel protection criteria already exists or is needed to meet the goals of reducing runoff volume and peak flows to less than existing levels on lands being developed or redeveloped, the use of more restrictive criteria may be required.
- ***Flood Control:*** For storms exceeding the 2-year, 24-hour event, an outlet structure must restrict the peak discharge rate for the 25 year storm whose duration equals the peak time of concentration. Adequate storage volume to achieve this peak flow reduction is required on the development site. The overland emergency flow relief path must be identified and designed for the 100-year, 24-hour design storm.

The low-impact analysis and design approach focuses on the following hydrologic analysis and design components:

- ***C:*** Minimizing change in the post-development C by reducing impervious areas and preserving more trees and meadows to reduce the storage requirements to maintain the pre-development runoff volume.
- ***Tc:*** Maintaining the pre-development Tc by minimizing the increase of the peak runoff rate after development by lengthening and flattening flow paths and reducing the length of the piped runoff conveyance systems.
- ***Retention:*** Providing retention storage for volume and peak control, as well as water quality control, to maintain the same storage volume as the pre-development condition.
- ***Detention:*** Providing additional detention storage, if required, to maintain the same peak runoff rate and/or prevent flooding and erosion downstream.

Table 2.1 provides a summary of Green Infrastructure techniques that affect these components.

Table 2.1. Green Infrastructure Techniques and Hydrologic Design and Analysis Components

	Green Infrastructure Technique															
Low-Impact Hydrologic Design and Analysis Components	Flatten slope	Increase flow path	Increase sheet flow	Increase roughness	Minimize disturbance	Flatten slopes on swales	Infiltration swales	Vegetative filter strips	Constricted Pipes	Disconnected impervious areas	Reduce curb and gutter	Rain barrels	Rooftop storage	Bioretention	Revegetation	Vegetation preservation
Lower Post-Development C					□		□	□		□	□			□	□	□
Increase Tc	□	□	□	□		□		□	□	□	□	□	□	□	□	□
Retention							□	□				□	□	□	□	□
Detention						□			□			□	□			

2.4 Hydrologic Evaluation (Used for the Establishment of Pre- and Post-Development Peak Flows and Volumes.)

The design of all facilities should be based on the design storm return interval; i.e., the probability that the storm will occur in any one year. For example, the 100-year storm has a one percent probability of being met or exceeded in any one year. The 25-year storm has a four percent probability of being met or exceeded in any one year. The return interval design criteria for Stormwater-related facilities are presented below.

The selection of the design storm for the sizing of any particular Stormwater management facility should consider the existence and adequacy of an Emergency Overland Flow Path and the risks to public safety and property should a storm event of greater intensity and duration occur. If the Emergency Overland Flow Path is inadequate, nonexistent, or uncertain, or if there are unacceptable risks to public safety and property, then the design engineer should consider a more appropriate and conservative design storm than the minimums suggested in this manual.

TABLE 2.2
DESIGN STORMS FOR NEW FACILITIES

Type of Facility	Design Storm	Duration
Conveyance Systems		
(Open Channel and/or Pipe)		
Temporary Construction Channel	5-year	Storm Drain Pipes
Minor System	10-year	Time of Concentration
Major System	25 to 100-year	Time of Concentration
Detention/Retention facilities		
Channel Protection	2-year	24-Hour
With Adequate downstream floodways	25-year	24-Hour
Without Adequate downstream floodways	100-year	24-Hour

The *minor* system of a drainage system includes the inlets, manholes, street gutters, ditches, and swales that collect the local runoff from adjacent land surfaces. This system collects runoff and transports it to a proper outlet, which is often part of the major system.

The *major* system primarily consists of natural waterways, large storm sewers, and large water impoundments, but it can also include less obvious drain ways, such as overland relief swales and infrequent temporary ponding at storm sewer inlets. The major system includes not only the trunk line drain that receives the water from the minor system, but also the natural flow path that functions in case of overflow from or failure of the minor system. Properly designed overflow relief will not flood or damage homes, businesses, or other property. It must always be remembered that the major system will function whether or not it has been planned and designed, and whether or not development is situated wisely with respect to it.

Rainfall values for the various design storm frequencies and durations can be obtained using the intensity-duration-frequency (IDF) data presented in Table 2.3.

When a runoff hydrograph is required, a design storm event should be used as input to hydrologic calculations. The selection of the storm duration and distribution affects the resulting runoff volume and the peak discharge rate. Because of this, the total storm volume and distribution should be selected to produce total runoff volume and peak runoff rates that are independent of the tributary area. The following characteristics of the design storm are suggested:

1. A minimum 24-hour rainfall volume (2.2 inches) should be used.

2. Soil infiltration rates will be necessary to determine if draw down can be accomplished within 72 hours after a rain event. Infiltration rates cannot be used to decrease the necessary runoff volume. *(Minimize compaction and contain sediment during construction process.)*

3. Groundwater mounding. If a detention basin is proposed, proof of no adverse impact from groundwater mounding must be provided.

4. The rainfall time distribution for the design storm should be in accordance with the Soil Conservation Service (SCS) Type II Rainfall Distribution as presented in Table 2.4, which includes data for the 100-year, 25-year, 10-year, and 2-year, 24-hour design storms for the Battle Creek area.

Figure 2.3
RAINFALL DEPTH AND INTENSITY CURVES
For Battle Creek, Michigan

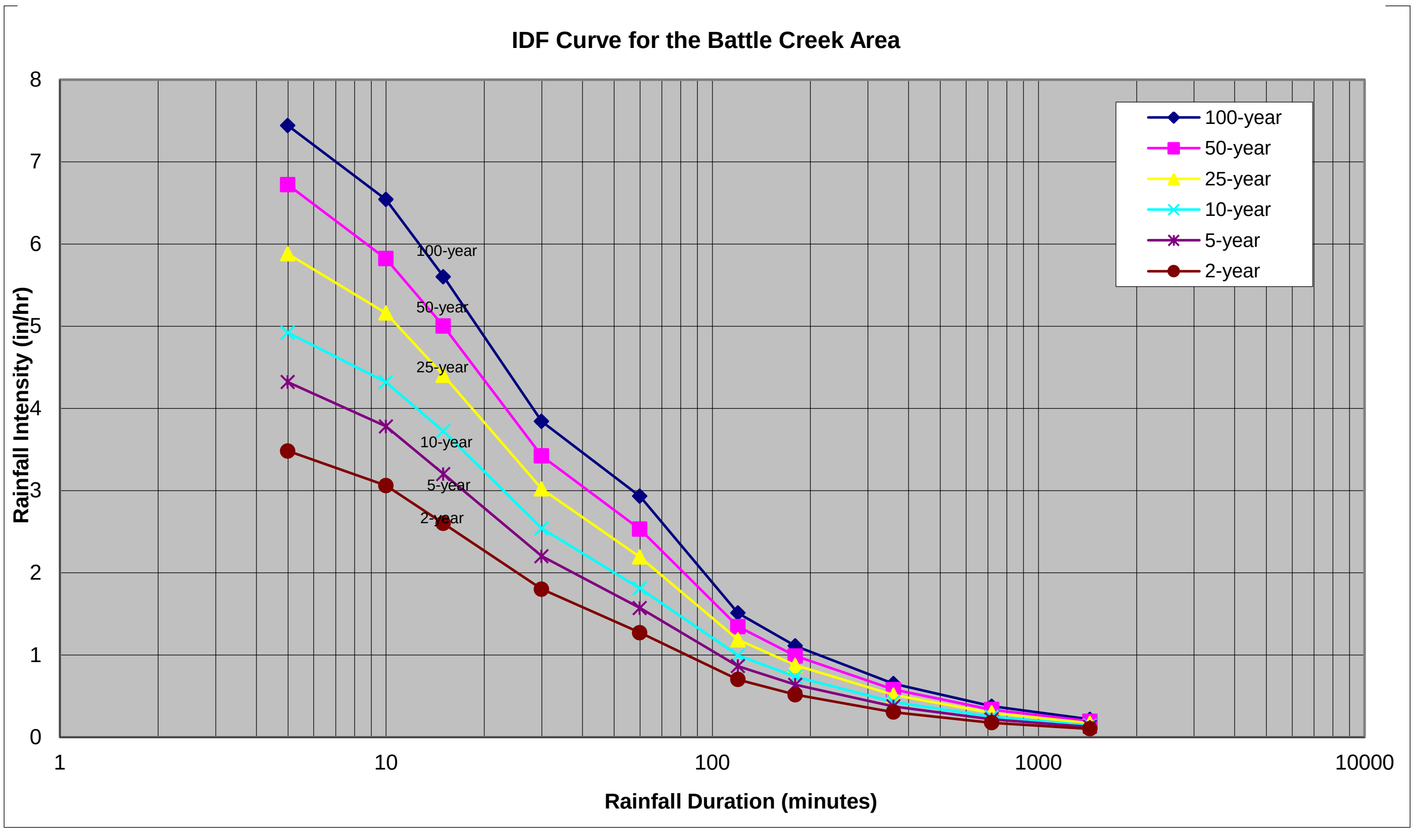


Table 2.3
RAINFALL DEPTH AND INTENSITY DATA
for Battle Creek, Michigan

VOLUME (INCHES RAINFALL)										
	5 Min	10 Min	15 min	30 Min	1 Hour	2 Hour	3 Hour	6 Hour	12 hour	24 Hour
2-year	0.29	0.51	0.65	0.90	1.14	1.40	1.55	1.82	2.11	2.42
5-year	0.36	0.63	0.80	1.10	1.40	1.73	1.91	2.24	2.59	2.98
10-year	0.41	0.72	0.93	1.27	1.61	1.99	2.20	2.57	2.98	3.43
25-year	0.49	0.86	1.10	1.51	1.92	2.37	2.62	3.07	3.56	4.09
50-year	0.56	0.97	1.25	1.74	2.18	2.69	2.96	3.47	4.03	4.63
100-year	0.62	1.09	1.40	1.92	2.44	3.02	3.33	3.90	4.52	5.20

RAINFALL INTENSITY (INCHES/HOUR)										
	5 Min	10 Min	15 min	30 Min	1 Hour	2 Hour	3 Hour	6 Hour	12 hour	24 Hour
2	3.48	3.06	2.60	1.80	1.14	0.70	0.52	0.30	0.18	0.10
5	4.32	3.78	3.20	2.20	1.40	0.87	0.64	0.37	0.22	0.12
10	4.92	4.32	3.72	2.54	1.61	1.00	0.73	0.43	0.25	0.14
25	5.88	5.16	4.40	3.02	1.92	1.19	0.87	0.51	0.30	0.17
50	6.72	5.82	5.00	3.42	2.18	1.35	0.99	0.58	0.34	0.19
100	7.44	6.54	5.60	3.84	2.44	1.51	1.11	0.65	0.38	0.22

Source: Huff, F.A. and Angel, Jr., "Rainfall Frequency Atlas of the Midwest" MCC Research Report 92-03, Midwestern Climate Center and Illinois State Water Survey (Bulletin 71)

Table 2.4
SCS TYPE II RAINFALL DISTRIBUTION DATA
for Battle Creek, Michigan

	SCS	100-year	25-year	10-year	2-year
HOUR	Type II Ratio	5.2 inches	4.09 inches	3.43 inches	2.42 inches
0	0.000	0.00	0.00	0.00	0.00
1.5	0.006	0.03	0.02	0.02	0.01
1.0	0.006	0.03	0.02	0.02	0.01
1.5	0.006	0.03	0.02	0.02	0.01
2.0	0.006	0.03	0.02	0.02	0.01
2.5	0.006	0.03	0.02	0.02	0.01
3.0	0.006	0.03	0.02	0.02	0.01
3.5	0.006	0.03	0.02	0.02	0.01
4.0	0.006	0.03	0.02	0.02	0.01
4.5	0.008	0.04	0.03	0.03	0.02
5.0	0.008	0.04	0.03	0.03	0.02
5.5	0.008	0.04	0.03	0.03	0.02
6.0	0.008	0.04	0.03	0.03	0.02
6.5	0.010	0.05	0.04	0.03	0.02
7.0	0.010	0.05	0.04	0.03	0.02
7.5	0.010	0.05	0.04	0.03	0.02
8.0	0.012	0.06	0.05	0.04	0.03
8.5	0.012	0.06	0.05	0.04	0.03
9.0	0.013	0.07	0.06	0.05	0.03
9.5	0.015	0.08	0.06	0.05	0.04
10.0	0.017	0.09	0.07	0.06	0.04
10.5	0.023	0.12	0.09	0.08	0.06
11.0	0.029	0.15	0.12	0.10	0.07
11.5	0.046	0.24	0.19	0.16	0.11
12.0	0.365	1.90	1.49	1.25	0.88
12.5	0.069	0.36	0.28	0.24	0.17
13.0	0.037	0.19	0.15	0.13	0.09
13.5	0.025	0.13	0.10	0.09	0.06
14.0	0.019	0.10	0.08	0.07	0.05
14.5	0.017	0.09	0.07	0.06	0.04
15.0	0.015	0.08	0.06	0.05	0.04
15.5	0.013	0.07	0.06	0.05	0.03

16.0	0.012	0.06	0.05	0.04	0.03
16.5	0.012	0.06	0.05	0.04	0.03
17.0	0.010	0.05	0.04	0.03	0.02
17.5	0.010	0.05	0.04	0.03	0.02
18.0	0.010	0.05	0.04	0.03	0.02
18.5	0.008	0.04	0.03	0.03	0.02
19.0	0.008	0.04	0.03	0.03	0.02
19.5	0.008	0.04	0.03	0.03	0.02
20.0	0.008	0.04	0.03	0.03	0.02
20.5	0.006	0.03	0.02	0.02	0.01
21.0	0.006	0.03	0.02	0.02	0.01
21.5	0.006	0.03	0.02	0.02	0.01
22.0	0.006	0.03	0.02	0.02	0.01
22.5	0.006	0.03	0.02	0.02	0.01
23.0	0.006	0.03	0.02	0.02	0.01
23.5	0.006	0.03	0.02	0.02	0.01
24.0	0.006	0.03	0.02	0.02	0.01

2.4.1 Land Use Conditions

Runoff calculations for all tributary drainage areas should be based on anticipated future land use conditions or existing land use conditions, whichever yields the greater runoff. Anticipated future land use conditions can include the impact of existing storage facilities. Future detention facilities may be used for anticipated future land use conditions, if approved by the reviewing agency.

2.4.2 Existing Depressional Storage

Existing depressional storage volume should be maintained, and the volume of detention storage provided to meet the release rate requirements of these guidelines should be in addition, to the existing depressional storage.

2.4.3 Watershed Boundary Transfers

All drainage areas and all waters tributary to, through, and from the project site should be accounted for. Watershed boundary transfers of runoff should be avoided unless no reasonable alternative exists and there is no legal restraint preventing such transfer. Downstream impacts resulting from transfers must be evaluated and properly accounted for.

2.4.4 Hydrologic Calculations

Two categories of hydrologic calculations are generally considered. The first involves establishing a peak flow for the sizing of storm drainpipes, culverts, or open channels. The second involves the routing of peak flows through BMPs to achieve pre-development hydrology (Green Infrastructure). Possible methods for each category of calculations are briefly discussed below. More details on hydrologic calculations appear in books by Linsley, Kohler and Paulhus (1983), Bedient and Huber (1988), Chow, Maidment and Mays (1988) or Wanilista and Yousef (1993).

1. **Peak Flow Estimation for Conveyance.** The two peak flow methods recommended for establishing peak flows for sizing storm drainage systems, culverts or open channels are the Rational Method or a computer model, HEC-1 or SWMM. In general, as the time of concentration, drainage area, and variability in land use increase, more complex procedures are warranted. A rule-of-thumb is that flood hydrograph procedures should be considered when the time of concentration exceeds the range of 30 to 45 minutes. Also consider the size and complexity of the storm drainage system. The use of SWMM in the absence of calibration data should only be performed by an experienced SWMM model user.

   a. **Rational Method** The Rational Method is an empirical method best suited for use on smaller storm drainage systems. The method requires calculating the tributary area, time of concentration, rainfall intensity, and runoff coefficient at each design point. The Rational Method equation is as follows:

   $$Q = CiA \qquad (5\text{-}1)$$

   Where: Q = Peak Flow Rate, in cfs
   C = Runoff Coefficient (See Table 2.5)
   i = Rainfall intensity in inches/hour, for the drainage area time of concentration, in minutes
   A = Drainage area, in acres

   The time of concentration is the sum of the inlet travel time and the storm drain pipe travel time, and must be calculated for each design point considered. Rainfall intensity is obtained from an intensity-duration frequency (IDF) curve based on the time of concentration and design frequency. The runoff coefficient should be the composite factor based on tributary land use and soil conditions.

   b. **Computer Model.** The HEC-1 or SWMM computer models are accepted for hydrologic peak flow calculations with supporting data.

2. **Peak Flow Estimation for Green Infrastructure Storage.** The Green Infrastructure and/or detention storage routing procedures presented in this manual include the Modified Rational Method, HEC-1, and SWMM. Additional information on these and other methods can be found in books by authors such as Maidment (1993) and by Chow, Maidment, and Mays (1988).

Table 2.5

RUNOFF COEFFECIENTS[a]
FOR
VARIOUS LAND USES, SOILS AND SLOPES

Slope	Typical Land Use	Sandy Soils		Clay Soils	
		Min.	Max.	Min.	Max.
Flat	Woodlands	0.10	0.15	0.15	0.20
(0-2%)	Pasture, grass, and farmland[b]	0.15	0.20	0.20	0.25
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements[c]	0.75	0.95	0.90	0.95
Rolling	Woodlands	0.15	0.20	0.20	0.25
(2-7%)	Pasture, grass, and farmland[b]	0.20	0.25	0.25	0.30
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements[c]	0.80	0.95	0.90	0.95
Steep	Woodlands	0.20	0.25	0.25	0.30
(7%+)	Pasture, grass, and farmland[b]	0.25	0.35	0.30	0.40
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements[c]	0.85	0.95	0.91	0.95

[a]Weighted coefficient based on percentage of impervious surfaces and green areas must be selected for each site.

[b]Coefficients assume good ground cover and conservation treatment.

[c]Depends on depth and degree of permeability of underlying strata.

Reference: DeKalb County, Georgia. (1976)

Modified Rational Method: This simple mass balance approach assumes that rainfall volume accumulates with time in relation to the rainfall IDF curves, as presented in Figure 5.3 for Battle Creek. The Rational Method runoff coefficient is used to convert rainfall to runoff volume. A tabular summary of results is used to determine the maximum difference between the cumulative inflow and cumulative outflow. This maximum represents an estimate of the required storage volume to achieve the desired outflow rate. An example tabulation of the Modified Rational Method calculations is presented in Table 5.6 for a runoff coefficient of 0.75 and a calculated predevelopment release rate of 0.3 cfs/acre. Calculations for pre-development release rate must be provided. Actual designs will need to calculate Pre-development Release Rates, excluding on-site storage. The 0.3 cfs/acre is used here to simplify this example. To account for the fact that the rate of discharge will vary with depth, an outflow adjustment factor of 0.9 was used.

Table 2.6

Example Use of the Modified Rational Method for Estimating Detention Storage Volumes

Time (hrs)	25-year Rainfall Intensity[a]	Runoff Volume C=0.75[b] (ft^3/acre)	Predevelopment Release Rate (cfs/acres)	Outflow Volume X 0.9 (ft^3/acre)[c]	Storage Volume (ft^3/acre)[d]
0.50	3.02	4,111	0.3	486	3625
1.00	1.92	5,227	0.3	972	4255
1.50	1.56	6,371	0.3	1458	4913
2.00	1.19	6,480	0.3	1944	4536

[a]From Table 2.3
[b]Rainfall intensity (in/hr) times runoff coefficient (.75) times a duration in hours, divided by 12 in/ft, times 43,560 ft^2/acre
[c]Release rate (0.3 cfs/ac) times a duration in seconds.
[d]Runoff volume minus the outflow volume
[e]Required storage volume for this example = 5,739 ft^3/acre.

The Modified Rational Method can be used in conjunction with BMPs in series for Green Infrastructure. Refer to Section 6.0 for recommended Retention/Detention BMPs.

2.5 Hydraulic Calculations for Sizing Stormwater Conveyance

Hydraulic calculations will be used to size conduits or open channels to handle the design flows calculated from hydrologic calculations (see Section 5.4). The hydraulic capacity of a storm drain conduit or culvert can be calculated for the two types of conditions typically referred to as gravity and pressure flow. Open channel facilities are evaluated considering only gravity flow.

Hydraulic procedures provided in this section represent a summary of information from publications by Brater and King (1976), Chow (1959), the American Society of Civil Engineers (1992), the University of Missouri (1958), the American Iron and Steel Institute (1980), and the American Concrete Pipe Association (1978 and 1980). These publications should be consulted if additional details are required.

2.5.1 Pressure Versus Gravity Flow

In general, if the hydraulic grade line is above the crown of a pipe, pressure flow hydraulic calculations are appropriate. Conversely, if the hydraulic grade line is below the crown of a pipe, gravity flow calculations are appropriate. Storm drainpipes should generally be designed as gravity systems.

For storm drainpipes designed to operate under pressure flow conditions, inlet surcharging and possible manhole Green Infrastructure displacement can occur if the hydraulic grade line rises above the ground surface. A design based on gravity conditions must be carefully planned as well, including evaluation of the potential for excessive and inadvertent flooding created when a storm event larger than the design storm pressurizes the system.

Existence of the desired flow condition should be verified for design conditions. Storm drainpipes can alternate between pressure and gravity flow conditions from one section to another.

The outlet point of the storm drainpipe usually establishes a starting point for evaluating the condition of flow. If the outlet is submerged, as when the water level of the receiving waters is above the crown of the pipe, the exit loss should be added to the water level and calculations for head loss in the storm drain pipe start from this point. If the hydraulic grade line is above the pipe crown at the next upstream manhole, pressure flow conditions exist; if it is below the pipe crown, then gravity flow calculations should be used at the upstream manhole.

When the outlet point is not submerged, a flow depth should be calculated at a known control section to establish a starting elevation. The hydraulic grade line is then projected from the starting elevation to the upstream manhole unless flow is super-critical, and then calculations start upstream and go in the downstream direction. Pressure flow calculations may be used at the manhole if the hydraulic grade is above the pipe crown.

The assumption of straight hydraulic grade lines is not entirely correct, since backwater and drawdown conditions can exist, but is generally reasonable. It is also usually appropriate to assume the hydraulic grade calculations begin at the crown of the outlet pipe for simple, nonsubmerged systems. If additional accuracy is needed, as with very large conduits or where the result can greatly affect design, backwater and drawdown curves should be developed.

2.5.2 Energy Losses

The following major energy losses should be considered for storm sewer systems:
Friction
Entrance
Exit

Additional energy loss parameters should be evaluated for complex or critical systems. The following pipe form losses are especially important when failure to handle the design flood has the potential to flood off-site areas:
Expansion
Contraction
Bend
Junction and manhole

The energy loss coefficient, K, is different for each category of pipe form loss and should be based on operating characteristics of the specific system. Values for the entrance loss coefficient are the same as those developed for culverts (see Table 5.9). Expansion and contraction loss coefficients for circular pipes can be selected based on data from Brater and King (1976).

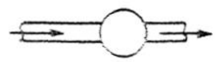
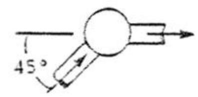
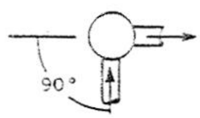
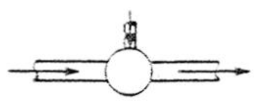
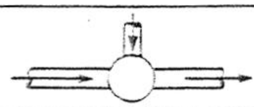
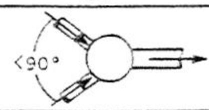
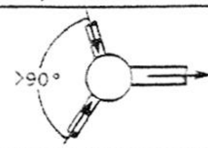
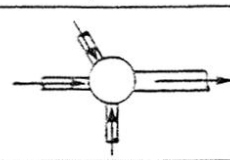
The bend loss coefficient for storm sewer systems can be evaluated using a graphical relationship between the angle of a bend and the loss coefficient, as presented by the Denver Regional Council of Governments (1969).

Losses associated with junctions and manholes should be evaluated with the procedures reported by the University of Missouri (1958). Although details of the procedures are not given in this manual, the application of important results is discussed below; and head loss coefficients for typical manholes and junctions are presented in Table 5.7.

For straight flow-through conditions, the University of Missouri (1958) indicates that pipes should be positioned vertically between the limits of inverts aligned or crowns aligned. An offset in the plan is allowed if the projected area of the smaller pipe falls within that of the larger.

TABLE 2.7

HEAD LOSS COEFFICIENTS FOR MANHOLES/JUNCTIONS

Type of Manhole/Junction		Head Loss Coefficient (K)
Single Pipe Junctions		
Trunkline only with no bend at junction		0.5
Trunkline only with 45° bend at junction		0.6
Trunkline only with 90° bend at junction		0.8
Multiple Pipe Junctions		
Trunkline with one small lateral		0.6
Trunkline with one large lateral		0.7
Two roughly equivalent entrance lines with angle of <90° between lines		0.8
Two roughly equivalent entrance lines with angle of >90° between lines		0.9
Three or more entrance lines		1.0

Reference: Golding (1987).

Note: Above values of K are to be used to estimate energy or head losses through surcharged junctions/manholes in pressure flow portions of a storm sewer system. The energy loss equation is

$$h_j(ft) = K \frac{[v(ft/sec)]^2}{64.4}$$

with v = larger velocity in main entrance or exit line of junction/manhole.

It is probably most effective to align the pipe inverts, as the manhole bottom will then support the bottom of the jet issuing from the upstream pipe.

When two laterals intersect at a manhole, pipes should not be oppositely aligned, since the two jets could impinge upon each other. If directly opposing laterals are necessary, install a deflector to reduce losses. The research conducted on this type of deflector is limited to the ratios of outlet pipe to lateral pipe diameters equal to 1.25. In addition, lateral pipes should be located such that their centerlines are separated laterally by at least the sum of the two lateral pipe diameters.

Flow components from upstream and lateral pipes should be considered when attempting to shape the inside of manholes. Results for pressurized pipe flow conditions reported by the University of Missouri (1958) indicate that very little, if anything, is gained by shaping the bottom of a manhole to conform to the pipe invert. Shaping the manhole bottom to match the pipe invert may even be detrimental when pressurized laterals flowing full are involved, as the shaping tends to deflect the jet upwards, causing unnecessary head loss. Limited shaping of the manhole bottom for open channel flow conditions is recommended.

2.5.3 Gravity Flow

The capacity of storm drain pipes and open channels designed to operate under gravity flow conditions should be sized using Manning's Equation as presented below:

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2} \qquad (5\text{-}2)$$

Where: Q = flow, in cubic feet per second
A = cross sectional area, in square feet
n = Mannings coefficient of roughness
R = hydraulic radius = A/P, in feet
P = wetted perimeter, in feet
S = slope of the energy gradient, in ft/foot

Storm drain pipes or open channel capacity calculations based on Manning's Equation can be made using procedures published by Brater and King (1976), the American Concrete Pipe Association (1978 and 1980), Chow (1959), and the American Iron and Steel Institute (1980).

2.6 Guidelines For Conveyance Systems

2.6.1 Easement and Operation Agreements

For those developments where Stormwater detention/retention facilities will be turned over to the reviewing agency, easement documents must be executed. Terms of the standard easement documents used by the reviewing agency are presented in Appendix A. One easement document applies to plats and the other does not.

When Stormwater detention/retention facilities are to be maintained as private property when the development is performed, a detention basin operation agreement must be executed

2.6.2 Residential Connections

Residential runoff from roofs and driveways, and discharges from sump pumps not discharging to a nearby detention/retention basin, should be directed onto vegetated surfaces for a distance of at least 50 feet. The direct connection of downspouts and sump pumps to storm sewers is discouraged unless clay or silty soils dominate the site, or insufficient site area is available. In such cases, additional compensating actions/facilities may be required.

2.6.3 Conveyance Systems

2.6.3.1 Emergency Overland Flow Way Easement

Whenever a Stormwater facility is constructed for a design storm less than the 100-year storm (base flood) an emergency overland flow path and easements should be provided to convey or store that portion of the 100-year runoff, which the facility does not manage. The easements are to be recorded with the County Register of Deeds.

2.6.3.2 Natural Channels

Natural stream and channel systems are to be preserved and fall under the jurisdiction of the MDEQ.

2.6.3.3 Channel Protection

Channel protection criteria is necessary to maintain post-development site runoff volume and peak flow rate at or below existing levels for all storms up to the 2-year, 24-hour event. "Existing levels" means the runoff flow volume and rate for the last land use prior to the planned new development or redevelopment. Where more restrictive channel protection criteria already exists or is needed to meet the goals of reducing runoff volume and peak flows to less than existing levels on lands being developed or redeveloped, the use of more restrictive criteria may be required.

2.6.4 Open Channels

2.6.4.1 Low Flow

Low-flow sections should be considered in the design of channels with large cross sections. Channels with design flows greater than 100 cfs will be considered to have large cross sections.

2.6.4.2 Cross Slopes

Channels with bottom widths over 10 feet should be designed with a minimum bottom cross slope of 12 to 1.

2.6.4.3 Side Slopes

Channel side slopes should be stable throughout the length and should consider the channel material and apply natural stabilization methods using native plantings, to the extent feasible.

2.6.4.4 Shape

Trapezoidal or parabolic cross sections are preferred; avoid triangular shapes.

2.6.4.5 Transitions

Channel section transition should be smooth and gradual. A straight line connecting flow lines at the two ends of the transition should not make an angle greater than 12.5 degrees with the axis of the main channel. Transition section length should be roughly ten times the upstream transition width. Energy losses in transitions should be accounted for as part of water surface profile calculations.

2.6.4.6 Velocity Limitations

The final design of artificial open channels should be consistent with the velocity limitations for the selected channel lining. Maximum velocity values for selected lining categories are presented in Table 2.8. Seeding and mulch should only be used when the design velocity does not exceed the allowable value for bare soil.

TABLE 2.8
MAXIMUM VELOCITIES FOR
COMPARING LINING MATERIALS

Material	Maximum Velocity[a,b] (feet/second)
Bare soil	1.50
Silt or fine sand	1.75
Sandy loam	2.00
Silt loam	3.75
Stiff clay	4.0
Sod and Lapped Sod	5.5
Vegetation[c]	Use Table 5.8-1
Rigid[a]	10

[a] Higher velocities may be acceptable for rigid linings if appropriate protection is provided.

[b] These are maximum velocities. For design purposes, use 60% of maximum velocities given in this table.

[c] The use of vegetative plants, especially native, are encouraged.

TABLE 2.8-1
MAXIMUM VELOCITIES FOR VEGETATIVE CHANNEL LININGS

Vegetation Type	Slope Range (%)	Maximum Velocity[a,b] (feet per second)
Bermuda grass	0-5	6
	5-10	5
Kentucky bluegrass	0-5	5
Buffalo grass	5-10	4

Grass mixture	0-5	4
Kudzu, alfalfa	5-10	3
Lespedeza sericea	0-5	2.5
Annuals	0-5	2.5

[a] Based on erosive soils

[b] These are maximum velocities. For design purposes, use 60% of maximum velocities in this table.

Reference: USDA, TP-61 (1947)

2.6.5 Culverts

2.6.2.1 Application Categories

For consistency, culvert applications are divided into two major categories, cross drains and side drains:

- **Cross Drain.** A cross drain is a culvert placed transversely under roadway sections, with end walls or some end treatment. Because cross-drain installations are normally under pavement. They should have at least premium joint-RCP to prevent soil migration. Leaking joints can cause uneven and differential settling of road surfaces or adjacent buildings.

- **Side Drain.** This culvert is generally a pipe used longitudinally in roadway ditches under driveways or graded connections.

- **Approvals.** Under Michigan State Law (Act 451, P.A. Part 301 of 1994 and Act 451, P.A. Part X of 1994), crossroad culverts draining two square miles or more must be reviewed and approved by the Michigan Department of Natural Resources.

Crossroad culverts draining less than two square miles of upstream watershed will be sized by the developer's engineer and approved by the reviewing agency.

2.6.2.2 Methods

Culverts should be sized using the nomographs presented in a USDOT, FHWA, HDS-5 (1985) report, "Hydraulic Design of Highway Culverts." As presented in that report, the two basic types of culvert control sections are inlet and outlet control. The control section for inlet control is just inside the entrance, and critical depth occurs at or near this location. The control section for outlet control is located at the barrel exit or downstream from the culvert. Either partially full sub critical flow or full pipe pressure flow conditions can occur.

If inlet control exists, the culvert barrel could possibly carry more flow than the inlet will accept, and if this is the case, a tapered inlet could be used to increase capacity up to the outlet capacity. If outlet control exists, the culvert barrel would have to be increased to add capacity. Once a culvert size has been determined from the nomograph, reductions may be warranted if storage occurs at the culvert embankment.

2.6.2.3 Allowable Headwater

The allowable headwater elevation can be established from an evaluation of land use upstream of the culvert and the proposed or existing roadway elevation. In general, the constraint that gives the lowest allowable headwater elevation should establish the basis for hydraulic calculations. The following criteria should be considered:

- **Flood Elevations** Non-damaging or permissible upstream flooding elevations (e.g., existing buildings or flood insurance rate map elevations) should be identified and headwater kept below them.

- **Maximum** Headwater depth for the design discharge should not exceed a height greater than 1.5 feet below the edge of the shoulder of a road.

- **Channel Capacity** Headwater depth for the design discharge should not cause water to rise above the top of approach channels adjacent to improved land or above the established floodplain elevations.

- **Backwater Impacts** Level pool backwater conditions should be evaluated upstream from the culvert to ensure that building flooding does not occur for the 100-year, 24-hour design storm.

2.6.2.4 Design Tailwater

The hydraulic conditions downstream of the culvert site should be evaluated to determine a tailwater depth for the design discharge. If the culvert outlet is operating in a free-fall outlet condition (e.g., a cantilever pipe), the critical depth and equivalent hydraulic grade line should be determined. For culverts that discharge to an open channel, the normal depth of flow in the channel must be evaluated. Guidance for performing these evaluations is available in the USDOT, FHWA (1985) report.

2.6.2.5 End Treatments

Selecting end treatment facilities should be consistent with hydraulic requirements, and give proper consideration to bank stability, safety, and costs. Entrance loss coefficients (K_e for the standard inlet patterns are summarized in Table 2.9.

TABLE 2.9

CULVERT ENTRANCE LOSS COEFFICIENTS

Type of Structure and Design of Entrance	Entrance Coefficient, Ke
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, square-cut end	0.5
Headwall or headway and wing walls	
Socket end of pipe (groove-end)	0.2
Square edge	0.5
Rounded (radius = 1/12 D)	0.2

Mitered to conform to fill slope	0.7
End section conforming to fill slope[a]	0.5
Beveled edges, 33.7º or 45º bevels	0.2
Side- or slope-tapered inlet	0.2
Pipe or Pipe Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headway or headwall and wing walls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
End section conforming to fill slope[a]	0.5
Beveled edges, 33.7º or 45º bevels	0.2
Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headway parallel to embankment (no wingwalls) Square-edged on three edges	0.5
Rounded on three edges to radius of 1/12 barrel dimension, or beveled edges on three sides	0.2
Wingwalls at 30º or 75º to barrel Square-edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.2
Wingwalls at 10º to 25º to barrel Square-edged at crown	0.5
Wingwalls parallel (extension of sides) Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

a. "End section conforming to fill slope," made of either metal or concrete, is the section commonly available from manufacturers. From limited hydraulic tests, the sections are equivalent in operation to a headwall in both inlet and outlet control. End sections that incorporate a closed taper in their design have a superior hydraulic performance.

Reference: USDOT, FHWA, HDS-5 (1985)

2.6.5.6 Velocity Limitations

Both minimum and maximum velocities should be considered when designing a culvert. A minimum velocity of 2.5 feet per second when the culvert is flowing full is recommended to ensure a self-cleaning condition during partial depth flow. When velocities below this minimum are anticipated, consider the installation of a sediment trap upstream of the culvert.

The maximum velocity should be consistent with channel stability requirements at the culvert outlet. As outlet velocities increase, the need for channel stabilization at the culvert outlet increases. If velocities exceed permissible velocities for the outlet lining material, the installation of outlet protection or energy dissipation may be necessary.

5.6.5.7 Length, Slope and Size

The length and slope of a culvert should be based on the channel bottom of the stream or channel being conveyed, the geometry of the roadway embankment, and the skew angle of the culvert. In general, the culvert slope should be chosen to approximate existing topography. The minimum culvert size is 12 inches.

2.6.6 Storm Drain Pipes

2.6.6.1 General Approach

The design of storm drainpipe systems is usually an iterative process involving the following four steps:

- **System Layout**. Selection of inlet locations and development of a preliminary plan and profile patterns.
- **Hydrologic Calculations.** Determination of design flow rates and volumes.
- **Hydraulic Calculations.** Determination of pipe sizes required to carry design flow rates and volumes.
- **Outfall Design.** Outlet protection to prevent erosion or detention/retention to control peak discharge rates may be required because of site constraints or allowable release-rate restrictions.

2.6.6.2 Pipe Size and Length

A minimum pipe size of 12 inches shall be used, unless another size is approved by the reviewing agency. Designs should use standard pipe size increments. The span-by-height format is used for reporting box culvert dimensions; e.g., in the dimension l0 by 7, the span is 10 feet and the height is 7 feet.

Access spacing should not exceed 350 feet for conduits less than 54 inches in diameter and should not exceed 800 feet for those 54 inches and above without approval from the reviewing agency.

2.6.6.3 Slopes and Hydraulic Gradient

The standard recommended minimum slope for storm drainpipes should be that which will produce a velocity of 2.5 feet per second when the storm sewer is flowing full. For pipe less than l8 inches in diameter, the minimum grade should be 0.5 percent.

Systems should generally be designed for non-pressure conditions. When hydraulic calculations do not consider minor pipe form energy losses, such as expansion, contraction, bend, junction, and manhole losses, the elevation of the hydraulic gradient for design flood conditions should be at least l.0 foot below ground elevation. Generally, minor losses should be considered when the velocity exceeds 6 feet per second (lower if flooding could cause critical problems). If all minor energy losses are accounted for, it is usually acceptable for the hydraulic gradient to reach the gutter elevation.

2.6.6.4 Minimum Clearances

Minimum clearances for storm drainpipe should comply with the following criteria:

- **Road Base** A minimum of 1 foot is required between the bottom of the road base material and the outside crown of the storm sewer.

- **Utility Conflicts** For utility conflicts that involve crossing a storm drain alignment, the recommended minimum design clearance between the outside of the pipe and the outside of any conflicting utility should be 0.5 foot if the utility has been located accurately at the point of conflict. If the utility has been approximately located, the minimum design clearance should be l foot. Electrical transmission lines or gas mains should never come into direct contact with the storm drainpipe.

- **Utility Placement** Storm drainpipes should not be placed parallel to or below existing utilities, which could cause utility support problems. The recommended clearance is 2 feet extending from each side of the storm sewer and l: l side slopes from the trench bottom.

- **Manholes** When a sanitary line or other utility must pass through a manhole, a minimum l-foot clearance should be maintained between the bottom of the utility and the flow line of the storm drain pipe; however, a greater clearance is recommended. Flow will be less obstructed when the utility is placed above or as close as possible to the crown of the pipe.

2.6.7 Manning's n Values

Manning's formula, as presented in Chow (1959), is an accepted method for performing open-channel flow capacity calculations, when uniform flow conditions represent design conditions. The selection of an appropriate resistance coefficient, known as the Manning's n value, is a key variable that requires experience and can significantly affect the results obtained. This section provides a summary of standard tables and references, which provide a consistent basis for evaluating and assigning Manning's n values. The material begins with a general discussion of basic principles for assigning n values followed by information from tabular and photographic interpretations.

2.6.7.1 Basic Principles

The factors presented in this section should be studied and evaluated with respect to type of channel, degree of maintenance, seasonal requirements, and other considerations as a basis for selecting an appropriate design value of Manning's n. Consideration should also be given to the probable condition of the channel when the design event is anticipated. Values representing a freshly constructed channel are rarely appropriate as a basis for design capacity calculations.

The following basic principles should be considered when selecting the value of Manning's n:

- **Turbulence** Generally, retardance increases when conditions tend to induce turbulence and decreases when they reduce turbulence.

- **Physical Roughness** Consider the physical roughness of the bottom and sides of the channel. Fine particle soils on smooth, uniform surfaces result in relatively low values of n. Coarse materials, such as gravel or boulders, and pronounced surface irregularities cause higher values of n.

- **Vegetation** The value of n will be affected by the height, density, and type of vegetation. Consider the density and distribution of the vegetation along the reach and the wetted perimeter, the degree to which the vegetation occupies or blocks the cross section of flow at different depths, and the degree to which the vegetation may be bent (shingled) by flows of different depths. The n value will increase in the spring and summer as vegetation grows and foliage develops and will diminish in the fall as the vegetation becomes dormant.

- **Cross Section** Channel shape variations, such as abrupt changes in channel cross sections or alternating small and large cross sections will require somewhat larger n values than normal. These variations in channel cross sections become particularly important if they cause the flow to meander from side to side.

- **Meandering** A significant increase in the value of n is possible if severe meandering occurs in the alignment of a channel. Meandering becomes particularly important when frequent changes in the direction of curvature occur with relatively small radii of curvature.

- **Channel Stability** Active channel erosion or sedimentation will tend to increase the value of n, since these processes may cause variations in the shape of a channel. Also consider the potential for future erosion or sedimentation in the channel.

- **Obstructions** Obstructions such as log jams or deposits of debris will increase the value of n. The level of this increase depends on the number, type, and size of obstructions.

- **Field Observations** Deciding on natural channel n values requires field observations and experience. Special attention is required in the field to identify floodplain vegetation and to evaluate possible roughness variations with flow depth. To be conservative, it is better to use a higher resistance for capacity calculations and a lower resistance for stability calculations.

2.6.7.2 Tabular Interpretations

Recommended Manning's n values for artificial channels with rigid, unlined, temporary, and riprap linings are given in Table 5.10. Recommended values for vegetative linings should be calculated using Figure 5.4, which provides a graphical relationship between Manning's n values and the product of velocity times hydraulic radius for several vegetative retarding classifications (see Table 5.11).

For natural or excavated stream channels, Manning's n value may be estimated using Cowan's Equation (Cowan, 1956) as presented below and the coefficients in Table 5.12:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)n_5 \qquad (5\text{-}3)$$

where:

n = Manning's roughness coefficient for a natural or excavated channel

n_0 = Coefficient for channel lining material
(See Table 5.12)

n_1 = Coefficient for the degree of channel irregularity
(See Table 5.12)

n_2 = Coefficient for variations of the channel cross section
(See Table 5.12)

n_3 = Coefficient for the relative effect of channel obstructions
(See Table 5.12)

n_4 = Coefficient for channel vegetation
(See Table 5.12)

n_5 = Coefficient for the degree of channel meandering
(See Table 5.12)

Recommended Manning's n values for street and pavement gutters are presented in Table 5.13. Storm drain and culvert pipe recommended Manning's n values are reported in Table 5.14.

Figure 2.4

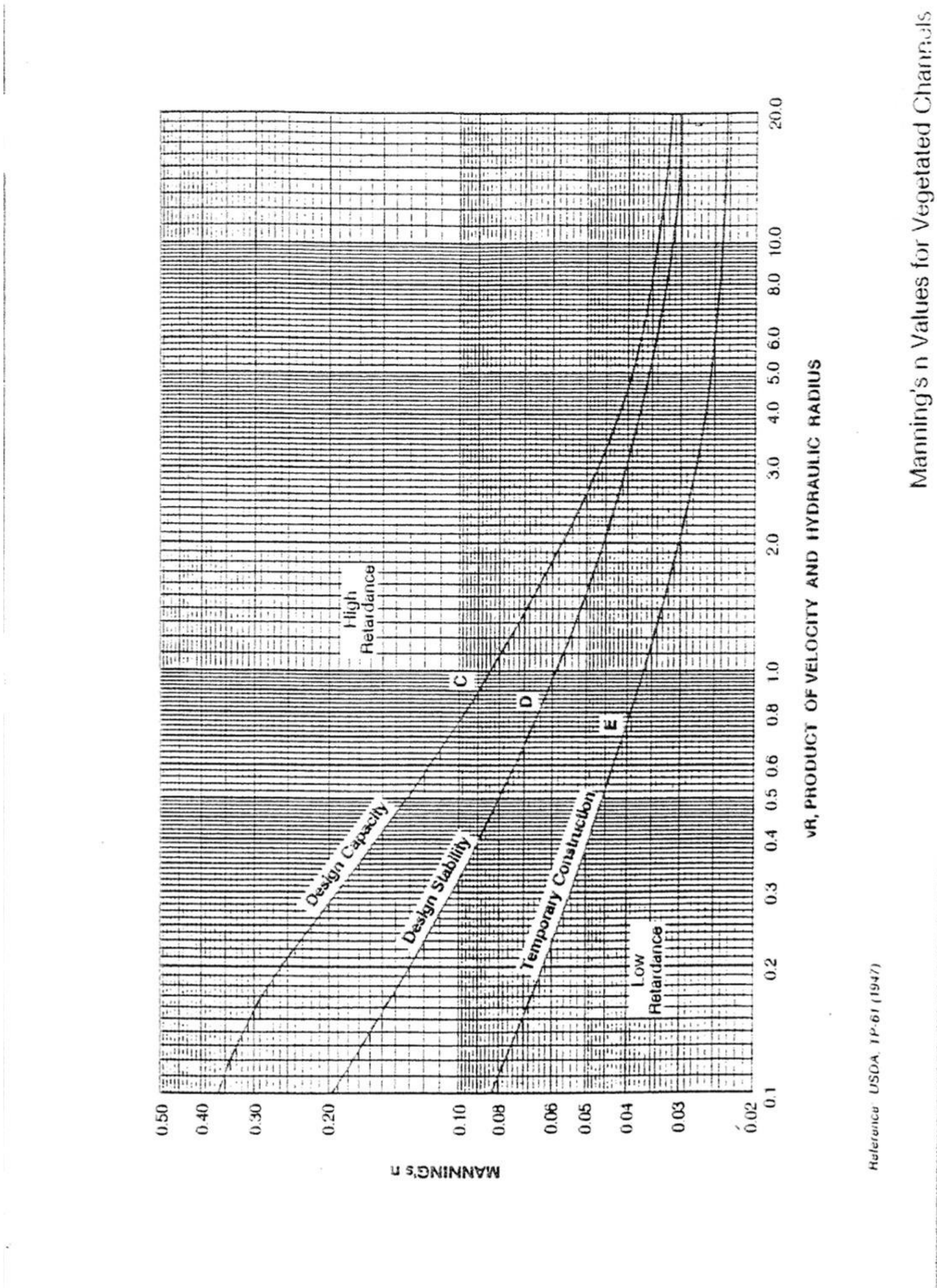

Manning's n Values for Vegetated Channels
MANNING'S n
vR, PRODUCT OF VELOCITY AND HYDRAULIC RADIUS
0.50
0.40
0.30
0.20
0.10
0.08
0.06
0.05
0.04
0.03
0.02
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1.0
2.0
3.0
4.0
5.0
6.0
8.0
10.0
20.0
High Retardance
Low Retardance
Design Capacity
Design Stability
Temporary Construction
C
D
E
Reference: USDA, TP-61 (1947)

TABLE 2.10
RECOMMENDED MANNING'S n VALUES

Lining Categorya	Lining Type	n Value for Depth of Flow Ranges		
		0-0.5 ft	0.5-2.0 ft	>2.0 ft
Rigid	Concrete (Broom or Float Finish	0.015	0.013	0.013
	Gunite	0.022	0.02	0.02
	Grouted Riprap	0.04	0.03	0.028
	Stone Masonry	0.042	0.032	0.03
	Soil Cement	0.025	0.022	0.02
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.023	0.02	0.02
	Rock Cut	0.045	0.035	0.025
Temporary	Woven Paper Net	0.016	0.015	0.015
	Jute Net	0.028	0.022	0.019
	Fiberglass Roving	0.028	0.021	0.019
	Straw with Net	0.065	0.033	0.025
	Curled Wood Mat	0.066	0.035	0.028
	Synthetic Mat	0.036	0.025	0.021
Gravel Riprap	1-inch (2.5-cm) d_{50}	0.044	0.033	0.03
	2-inch (5-cm) d_{50}	0.066	0.041	0.034
Rock Riprap	N/A	$n=0.0395 (d_{50})^{1/6}$		

FOR ARTIFICIAL CHANNELS

d_{50} = Diameter of stone for which 50 percent, by weight, of the gradation is finer, in feet

[a]n values for vegetative linings should be determined using Figure 5.4.
Reference: USDOT, FHWA, HEC-15 (1986).

TABLE 2.11
CLASSIFICATION OF PLANT COVERS AS TO DEGREE OF RETARDANCE

Retardance Class	Cover	Condition
A	Weeping lovegrass	Excellent stand, tall (average 30")(76 cm)
B	Kudzu	Very good growth, uncut
	Bermudagrass	Good stand, tall (average 12")(30 cm)
	Native grass mixture (little bluestem, bluestem, blue gamma, and other long and short midwest grasses)	Good stand, unmowed
	Weeping lovegrass	Good stand, tall (average 24")(61 cm)
	Lespedeza sericea	Good stand, not woody, tall (av.19")(48 cm)
	Alfalfa	Good stand, uncut (average 11")(28 cm)
	Weeping lovegrass	Good stand, unmowed (av. 13")(33 cm)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13")(33 cm)
C	Crabgrass	Fair stand, uncut (10 to 48")(25 to 122 cm)
	Bermuda grass	Good stand, mowed (average 6")(15 cm)
	Common lespedeza	Good stand, uncut (average 11")(28 cm)
	Grass-legume mixture summer (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 to 8")(15 to 20 cm)
	Centipedegrass	Very dense cover (average 6")(15 cm)
	Kentucky bluegrass	Good stand, headed (6 to 12")(28 cm)
D	Bermudagrass	Good stand, cut to 2.5-inch height (6 cm)
	Common lespedeza	Excellent stand, uncut (av. 4.5")(11 cm)
	Buffalo grass	Good stand, uncut (3 to 6")(8 to 15 cm)
	Grass-legume mixture - fall, spring (orchard grass, redtop, Italian rye grass, and common lespedeza)	Good stand, uncut (4 to 5")(10 to 13 cm)
	Lespedeza sericea	After cutting to 2" height (5 cm) Very good stand before cutting
E	Bermudagrass	Good stand, cut to 1.5-inch height (4 cm)
	Bermudagrass	Burned stubble

Note: Covers classified have been tested in experimental channels. Covers were green and generally uniform.
Reference: USDA, TP-61, (1947)

TABLE 2.12
COEFFICIENTS FOR COMPUTING MANNING'S n VALUES FOR NATURAL OR EXCAVATED CHANNELS USING COWAN'S EQUIPMENT[a]

Channel Conditions			Values[b]
Material Involved	Earth	n_o	0.020
	Rock Cut		0.025
	Fine Gravel		0.024
	Coarse Gravel		0.028
Degree of Irregularity	Smooth	n_1	0.000
	Minor		0.005
	Moderate		0.010
	Severe		0.020
Variations of Channel Cross Section	Gradual	n_2	0.000
	Alternating Occasionally		0.005
	Alternating Frequently		0.010-0.015
Relative Effect of Obstructions	Negligible	n_3	0.000
	Minor		0.010-0.015
	Appreciable		0.020-0.030
	Severe		0.040-0.060
Vegetation	Low	n_4	0.005-0.010
	Medium		0.010-0.025
	High		0.025-0.050
	Very High		0.050-0.100
Degree of Meandering	Minor	n_5	1.000
	Appreciable		1.150
	Severe		1.300

Notes:
a. Cowan's Equation presented as Equation 5-3.
b. From Chow (1959), Table 5-5, page 109

TABLE 2-13
MANNING'S n VALUES FOR STREET AND PAVEMENT GUTTERS

Type of Gutter or Pavement	Manning's n
Design value	0.014
Concrete gutter, troweled finish	0.012
Asphalt pavement	
Smooth texture	0.013
Rough texture	0.016
Concrete gutter with asphalt pavement	
Smooth	0.013
Rough	0.015
Concrete pavement	
Float finish	0.014
Broom finish	0.016
For gutters where sediment may accumulate, increase values of n by	0.002

Reference: USDOT, FHWA, HDS-3 (1961)

TABLE 2-14
MANNING'S n VALUES FOR STORM DRAIN AND CULVERT PIPE

Drain Type	Manning's n
Concrete pipes and box culverts (precast or cast-in-place)	0.013
CMP (nonspiral flow, annular corrugations)	0.024
CMP (full pipe spiral flow, helical corrugations)	
Sizes 15 - 24 inches	0.017
Sizes 30 - 54 inches	0.021
Sizes 60 - 96 inches	0.024

Notes:
1) New installations in Battle Creek shall be limited to concrete pipe.
2) Additional details for selecting roughness coefficients for CMP can be obtained from FHWA-TS-80-216 (USDOT, FHWA, 1980).

2.6.7.3 Photographic Interpretations

An independent check on the interpretation of field conditions using photographs can be accomplished using the Federal Highway Administration Report, FHWA-TS-84-204, (USDOT, FHWA, 1984). Photographs of typical channel and floodplain conditions are contained in this report with assigned Manning's values.

This report could be taken into the field to provide a guide for selecting n values if a photograph similar to actual field conditions is included in the report. An alternative would be to compare photographs obtained from the field to similar report photos, if available.

2.6.8 Outlet Protection

Transitions from closed conduits such as culverts, storm sewers, or flow concentrating devices create the potential for erosion and scour due to high velocities. The magnitude of this concern and the potential need for other outlet protection measures should be evaluated as part of the design of Stormwater management facilities. A general procedure for evaluating the need for outlet protection and for selecting and sizing corrective measures is presented in the Hydraulic Engineering Circular No. 14 "Hydraulic Design of Energy Dissipators for Culverts & Channels", published by the U.S. Department of Transportation, Federal Highway Administration (1983).

2.7 Stormwater Detention/Retention Guidelines

2.7.1 Outfalls

All new Stormwater outfalls should connect to a well-defined downstream system with adequate capacity to handle a concentrated flow. The maximum release rate from a Stormwater detention basin shall be no greater than the pre-development rate from the site for the 25-year, 24-hour design storm.

2.7.2 Emergency Overflow

An emergency overflow structure should be provided which is capable of passing the l00-year flow without damages to structures or adjacent property.

2.7.3 Freeboard

A minimum freeboard of 1 foot above the design high water elevation should be provided.

2.7.4 Minimum Pipe Size

Single pipe outlets should have a minimum inside pipe diameter of 12 inches, unless another size is approved by the reviewing agency. If design release rates call for smaller outlet dimensions, structures such as perforated risers or restrictive orifices, with debris control should be used.

2.7.5 Location Restrictions

Stormwater retention and detention facilities should not be constructed in a regulatory floodplain unless approved by the reviewing agency.

2.7.6 Buffer Zones

There should be a 50-foot buffer zone measured from the waterline of the design high-water elevation outward perpendicular to the waterline, around any detention or retention basin. No residential-type structure should be built within this buffer zone.

2.7.7 Sediment and Debris Removal

Basins should facilitate sedimentation of suspended materials and skimming of floating materials with adequate access for removal of sediment and trapped debris. Adequate maintenance access from public or private right-of-way to the basin will be reserved. The access will be on a slope of 5:1 or flatter, stabilized to withstand the passage of heavy equipment, and will provide direct access to both the forebay and the riser/outlet.

2.7.8 Dry Detention Dewatering

Dry basin bottoms should be sloped at least 2 percent toward the outlet or be equipped with adequate under drains to dewater the pond within 72 hours. To be considered dry, the outlet control elevation should be at least 1 foot below the pond bottom.

2.7.9 Off-site Areas

Runoff from off-site areas should be included when release rates are calculated for development sites, unless off-site runoff is routed around the development such that it does not mingle with on-site runoff.

2.7.10 Safety

Consideration shall be given to providing for the protection of the general public in the design of Stormwater detention or retention facilities. The design should identify public safety concerns relevant to the proposed facility. Slope conditions, fencing, screening or other measures shall be incorporated into the design of such facilities to reasonably minimize potential hazards. Providing safe retention/detention is the proprietor’s responsibility.

- **Basin Side Slopes** Basin side slopes should be no steeper than 1 foot of vertical rise for each 3 feet of horizontal distance. Sudden changes in slopes from shallow to steeper, creating a potential underwater drop-off, should be avoided.

- **Fencing** Fencing is recommended. Check local regulations or requirements before designing.

- **Outlet Protection** Debris-trapping facilities, with adequate access for cleanout and removal of trapped materials, should be placed at detention system outlet works. The design should be such that a person or child cannot be trapped by this facility. This may be accomplished by placing the debris-trapping facility a distance from the outlets' intake such that the flow velocities through the debris trap toward the outlet are about one (1) foot per second or less.

- **Emergency Overflow Structure** An emergency overflow structure should be provided for detention/retention system outlet works which is capable of passing the runoff from a design storm of a 24-hour duration and having a one percent chance of being equaled or exceeded in any given year, without damaging structures or property.

Appendix A

Glossary of Terms

Aquifer- A formation, group of formations, or part of a formation that contains sufficient saturated, permeable material to yield significant quantities of water to wells and springs.

"As-Built"- Drawing or certification of conditions as they were actually constructed.

Bioretention- A water quality practice that utilizes landscaping and soils to treat urban Stormwater runoff by collecting it in shallow depressions, before filtering it through a fabricated planting soil media.

Channel- A natural stream that conveys water; a ditch or channel excavated for the flow of water.

Channel Protection- The criteria is necessary to maintain post-development site runoff volume and peak flow rate at or below existing levels for all storms up to the 2-year, 24-hour event.

Channel Stabilization- Erosion prevention and stabilization of velocity distribution in a channel using jetties, drops, revetments, structural linings, vegetation and other measures.

Check Dam- A small dam constructed in a gully or other small watercourse to decrease the stream flow velocity (by reducing the channel gradient), minimize channel scour, and promote deposition of sediment.

Clay (Soils)- 1. mineral soil separate consisting of particles less than 0.002 millimeter in equivalent diameter. 2. A soil texture class. 3. (Engineering) A fine-grained soil (more than 50 percent passing the No. 200 sieve) that has a high plasticity index in relation to the liquid limit. (Unified Soil Classification System)

Compaction (Soils)- Any process by which the soil grains are rearranged to decrease void space and bring them in closer contact with one another, thereby increasing the weight of soGreen Infrastructure material per unit of volume, increasing the shear and bearing strength and reducing permeability.

Conduit- Any Channel intended for conveyance of water, whether open or closed.

Contour- 1. An imaginary line on the surface of the earth connecting points of the same elevation. 2. A line drawn on a map connecting points on the same elevation.

Crushed Stone- Aggregate consisting of angular particles produced by mechanically crushing rock.

Curve Number (CN)- A numerical representation of a given area's hydrologic soil group, plan cover, impervious cover, interception and surface storage derived in accordance with Natural Resources Conservation Service methods. This number is used to convert rainfall volume into runoff volume.

Cut- A portion of land surface or area from which earth has been removed or will be removed by excavation; the depth below original ground surface to excavated surface.

Cut-And-Fill- Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

Detention- The temporary storage of storm runoff in a SMP with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

Detention Structure- A structure for the purpose of temporary storage of stream flow or surface runoff and gradual release of stored water at controlled rates.

Disturbed Area- An area in which the natural vegetative soil cover has been removed or altered and, therefore, is susceptible to erosion.

Diversion- A channel with a supporting ridge on the lower side constructed across the slope to divert water from areas where it is in excess to sites where it can be used or disposed of safely. Diversions differ from terraces in that they are individually designed.

Drainage- 1. The removal of excess surface water or ground water from land by means of surface or subsurface drains. 2. Soils characteristics that affect natural drainage.

Drainage Area (Watershed)- All land and water area form which runoff may run to a common (design) point.

Dry Swale- An open drainage channel explicitly designed to detain and promote the filtration of Stormwater runoff through an underlying fabricated soil media.

Erosion- 1. The wearing away of the land surface by running water, wind, ice or other geological agents, including such processes as gravitational creep. 2. Detachment and movement of soil or rock fragments by water, wind, ice or gravity. The following terms are used to describe different types of water erosion:
Accelerated erosion- Erosion much more rapid than normal, natural or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophes that expose the base surfaces, for example, fires.

Erosion, Rill- An erosion process in which numerous small channels only several inches deep are formed. See rill.

Erosion, Sheet- The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not subsequently be removed by surface runoff.

Erosive Velocities- Velocities of water that are high enough to wear away the land surface. Exposed soil will generally erode faster than stabilized soils. Erosive velocities will vary according to the soil type, slope, structural, or vegetative stabilization used to protect the soil.

Extreme Flood (Qf)- The storage volume required to control those infrequent but large storm events in which overbank flows approach the floodplain boundaries of the 100 year flood.

Filter Bed- The section of a constructed filtration device that houses the filter media and the outflow piping.

Filter Fence- A geotextile fabric designed to trap sediment and filter runoff.

Filter Media- The sand, soil, or other organic material in a filtration device used to provide a permeable surface for pollutant and sediment removal.

Filter Strip- A strip of permanent vegetation above ponds, diversions and other structures to retard flow of runoff water, causing deposition of transported material, thereby reducing sediment flow.

Fines (Soil)- Generally refers to the silt and clay size particles in soil.

Floodplain- Areas adjacent to a stream or river that are subject to flooding or inundation during a storm event that occurs, on average, once every 100 years (or has a likelihood of occurrence of 1/100 in any given year).

Forebay- Storage space located near a Stormwater SMP inlet that serves to trap incoming coarse sediments before they accumulate in the main treatment area.

Grade- 1. The slope of a road, channel, or natural ground. 2. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction, like paving or laying a conduit. 3. To finish the surface of a canal bed, roadbed, top of embankment or bottom of excavation.

Grass Channel- An open vegetative channel used to convey runoff and to provide treatment by filtering out pollutants and sediments.

Gravel- 1. Aggregate consisting of mixed sizes of ¼ inch to 3-inch particles, which normally occur in or near old streambeds and have been worn smooth by the action of water. 2. A soil having particles sizes, according to the Unified Soil Classification System, ranging from the No.4 sieve size angular in shape as produced by mechanical crushing.

Ground Cover- Plants, which are low growing and provide a thick growth, which protects that soil as well as providing some beautification of the area, occupied.

Groundwater – Water beneath the surface of the earth that fills openings, known as pore spaces in sand, gravel, or fractured rock. Groundwater begins as rain or snow that passes through the soil and accumulates in the pore spaces.

Groundwater Mounding- A raised area in a water table or other potentiometric surface created by groundwater recharge. Mounding can alter groundwater flow rates and direction; however, the effects are usually localized and may be temporary, depending upon the frequency and duration of the surface recharge events.

Gully Erosion- The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging form 1 or 2 feet to as much as 75 to 100 feet.

Gully- A channel or miniature valley cut by concentrated runoff through which water commonly flows only during and immediately after heavy rains or during the melting of snow. The distinction between gully and rill is one of depth. A gully sufficiently deep that it would not be obliterated by normal tillage operations, whereas a rill is of lesser depth and would be smoothed by ordinary farm tillage.

Head (Hydraulics)- 1. The height of water above any plane of reference. 2. The energy, either kinetic or potential, possessed by each unit weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various terms such as pressure head, velocity head, and head loss.

Herbaceous Perennial (Plants)- A plant whose stems die back to the ground each year.

Hydraulic Gradient- The slope of the hydraulic grade line. The slope of the free surface of water flowing in an open channel.

Hydrograph- A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

Hydrologic Soil Group (HSG)- A Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential group. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability rates and produce much more runoff.

Hydro seed- Seed or other material applied to areas in order to revegetate after a disturbance.

Impervious Cover (I)- Those surfaces in the urban landscape that cannot effectively infiltrate rainfall consisting of building rooftops, pavement, sidewalks, driveways, etc.

Industrial Stormwater Permit- An NPDES permit issued to a commercial industry or a group of industries, which regulates the pollutant levels, associated with industrial Stormwater discharges or specifies onsite pollution control strategies.

Infiltration Rate (Fc)- The rate at which stormwater percolates into the subsoil measured in inches per hour.

Inflow Protection- A water handling device used to protect the transition area between any water conveyance (dike, swale, or swale dike) and a sediment trapping device.

Level Spreader- A device for distributing Stormwater uniformly over the ground surface as sheet flow to prevent concentrated, erosive flows and promote infiltration.

Manning's Formula (Hydraulics)- A formula used to predict the velocity of water flow in an open channel or pipeline:

V=(1.486 r2/3 s ½)/n

Where V is the mean velocity of flow in feet per second; R is the hydraulic radius; S is the slope of the energy gradient or for assumed uniform flow the slope of the channel, in feet per foot; and n is the roughness coefficient or retardance factor of the channel lining.

Mulch- Covering on surface of soil to protect and enhance certain characteristics, such as water retention qualities.

Municipal Stormwater Permit- An NPDES permit issues to municipalities to regulate discharges from municipal separate storm sewers for compliance with USEPA established water quality standards and/or to specify Stormwater control strategies.

NPDES- National Pollutant Discharge Elimination System permit, which regulates point source and non-point source discharge through the Clean Water Act. In Michigan, an NPDES permit is administered through MDEQ.

One Year Storm (QP1)- A Stormwater event, which occurs on average once every year or statistically has a 100% chance on average of occurring in a given year.

One Hundred Year Storm (QP100)- An extreme flood event, which occur on average of once every 100 years, or statistically has a 1% chance on average of occurring in given year.

Open Channels- Also known as swales, grass channels, and biofilters. These systems are used for conveyance, retention, infiltration and filtration of Stormwater runoff.

Outlet- The point at which water discharges from such things as a stream, river, lake, tidal basin, pipe, channel, or drainage area.

Outlet Channel- A waterway constructed or altered primarily to carry water from man made structures such as terraces, subsurface drains, diversions, and impoundments.

Peak Discharge Rate- The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Permanent Seeding- Results in establishing perennial vegetation, which may remain on the area for many years.

Permeability- The rate of water movement through the soil column under saturated conditions.

Permissible Velocity (hydraulics)- The highest average velocity at which water may be carried safely in a channel or other conduit. The highest velocity that can exist through a substantial length of a conduit and not cause scour of the channel. A safe, non-eroding or allowable velocity.

pH- A number denoting the common logarithm of the reciprocal of the hydrogen ion concentration. A pH of 7.0 denoted neutrality, higher values indicate alkalinity, and lower values indicate acidity.

Piping- Removal of soil material through subsurface flow channels or pipes developed by seepage water.

Plugs- Pieces of turf, sod, or plants usually cut with a round tube, which can be used to propagate the turf or sod by vegetative means.

Porosity- Ratio of pore volume to total soGreen Infrastructures volume.

Q – Rate of flow.

Redevelopment- New development activities on previously developed land.

Retention- The amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

Right Of Way- Right of passage, as over another’s property. A route that is lawful to use. A strip of land acquired for transport or utility construction.

Rip-Rap- Broken rocks, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves); also applies to brush or pole mattresses, or brush and stone, or similar materials used for soil erosion control.

Roughness Coefficients(hydraulics)- A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning’s “n” is a commonly used roughness coefficient.

Runoff (Hydraulics)- That portion of precipitation on a drainage area that is discharged from the area in the stream channels. Types include surface runoff, ground water runoff , and seepage.

Runoff Coefficient (Rv)- A value derived from a site impervious cover value that is applied to a given rainfall volume to yield a corresponding runoff value.

Sand- 1. (Agronomy) A soil particle between 0.05 and 2.0 millimeters in diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System, a soil particle larger than the No. 200 sieve and passing the No. 4 sieve.

Sediment- SoGreen Infrastructure material, both mineral and organic, that is in suspension, being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Seepage- 1. Water escaping through or emerging from the ground. 2. The process by which water percolates through the soil.

Seepage Length- In sediment basins or ponds, the length along the pipe and around the anti-seep collars that is within the seepage zone through an embankment.

Setbacks- The minimum distance requirements for locations of a structural SMP in relation to roads, wells, septic fields, and other structures.

Sheet Flow- Water, usually storm runoff, flowing in a thin layer over the ground surface.

Side Slopes (engineering)- The slope of the sides of a channel, dam or embankment. It is customary to name the horizontal distance first, as 1.5 to 1, or frequently, 1 ½:1, meaning a horizontal distance of 1.5 feet to 1 foot vertical.

Silt- 1. (Agronomy) A soil separate consisting of particles between 0.05 and 0.002 millimeters in equivalent diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System, a fine-grained soil (more than 50 percent passing the No. 200 sieve) that has a low plasticity index in relation to the liquid limit.

Soil Test- Chemical analysis of soil to determine needs for fertilizers or amendments for species of plants being grown.

Spillway- An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled to regulate the discharge of excess water.

Stabilization- Providing adequate measures, vegetative and/or structural that will prevent erosion from occurring.

Stage (Hydraulics)- The variable water surface or the water surface elevation above any chosen datum.

Stormwater Ponds- A land depression or impoundment created for the detention or retention of Stormwater runoff.

Stormwater Wetlands- Shallow, constructed pools that capture Stormwater and allow for the growth of characteristics wetland vegetation.

Stream Buffers- Zones of variable width, which are located along both sides of a stream and are designed to provide a protective natural are along a stream corridor.

Subgrade- The soil prepared and compacted to support a structure or a pavement system.

Temporary seeding- A seeding, which is made to provide temporary cover for the soil while waiting for further construction or other activity to take place.

Ten Year Storm(Qp10)- The peak discharge rate associated with a 24 hour storm event that occurs on average once every ten years (or has a likeliness of occurring 1/10 in a given year)

Time of Concentration- Time required for water to flow from the most remote point of a watershed, in a hydraulic sense, to the outlet.

Topsoil- Fertile or desirable soil material used to top road banks, subsoils, parent material, etc.

Total Suspended Soils- The total amount of soil particulate matter, including both organic and inorganic material, suspended in the water column.

Two Year Storm (Qp2)- The peak discharge rate associated with a 24-hour storm event that occurs on average once every two years (or has a likelihood of occurring ½ in a given year).

Velocity Head- Head due to the velocity of a moving fluid, equal to the square of the mean velocity divided by twice the acceleration due to gravity (32.16 feet per second per second).

Volumetric Runoff Coefficient (Rv)- The value that is applied to a given rainfall volume to yield a corresponding runoff volume based on the percent impervious cover in a drainage basin.

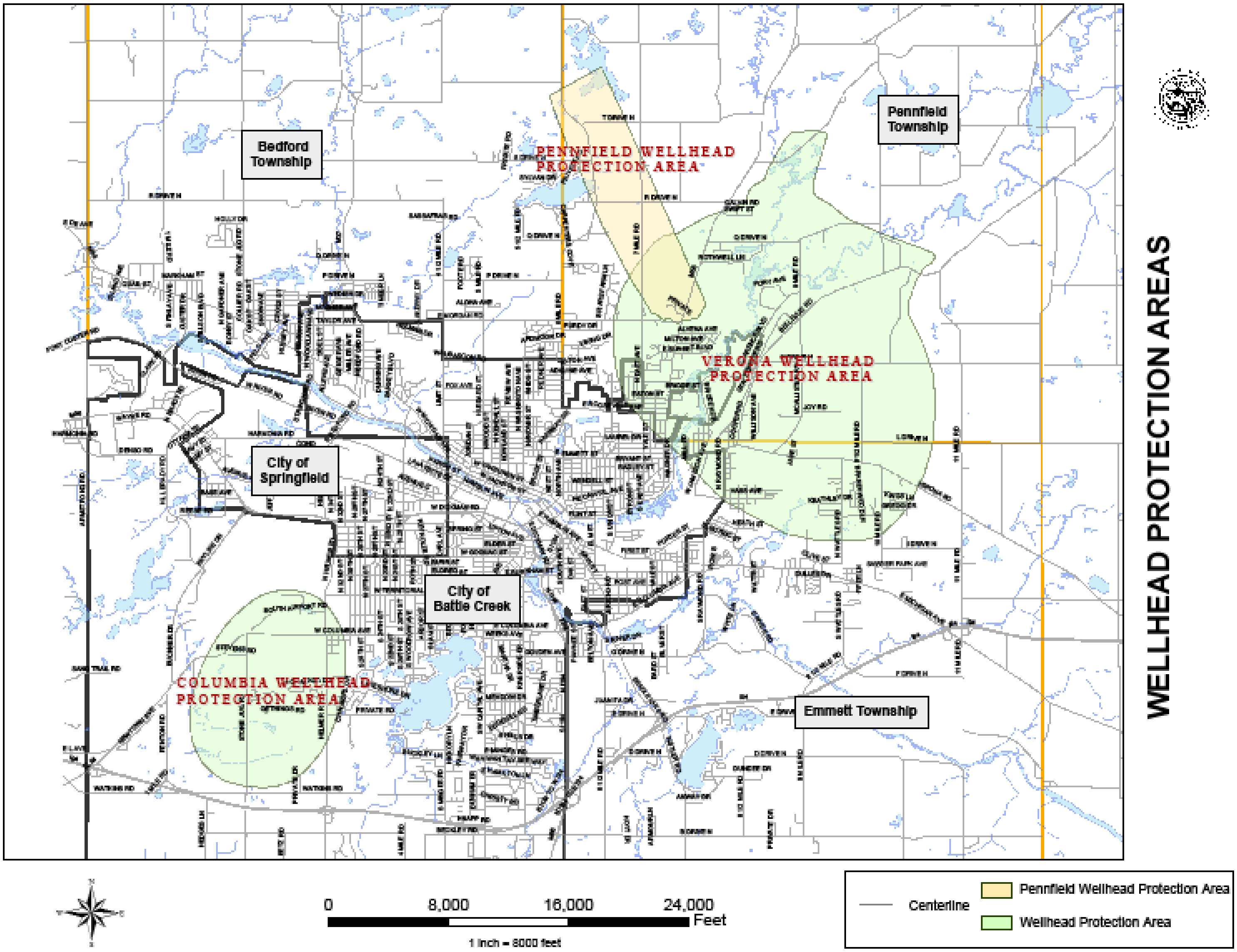
Water Quality Volume (WQv)- The storage needed to capture and treat 90%of the average annual Stormwater runoff volume.

Water Surface Profile- The longitudinal profile assumed by the surface of a stream flowing in an open channel; the hydraulic grade line.

Wet Swale- An open drainage channel or depression, explicitly designed to retain water or intercept ground water for water quality treatment.

APPENDIX B

Wellhead Protection Areas of Greater Battle Creek



APPENDIX C

EPA Fact Sheet: *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*

Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices

This fact sheet provides additional information about EPA's report *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, EPA publication number 841-F-07-006, December 2007.

BACKGROUND

Stormwater has been identified as a major source of pollution for all waterbody types in the United States, and the impacts of stormwater pollution are not static; they usually increase with land development and urbanization. The addition of impervious surfaces, soil compaction, and tree and vegetation removal result in alterations to the movement of water through the environment. As interception, evapotranspiration, and infiltration are reduced and precipitation is converted to overland flow, these modifications affect not only the characteristics of the developed site but also the watershed in which the development is located.

Parking lot runoff is allowed to infiltrate through a vegetated bioretention area

Low Impact Development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution. LID comprises a set of site design approaches and small-scale stormwater management practices that promote the use of natural systems for infiltration, evapotranspiration, and reuse of rainwater. These practices can effectively remove nutrients, pathogens, and metals from stormwater, and they reduce the volume and intensity of stormwater flows.

COST ANALYSIS

This report is an effort to compare the projected or known costs of LID practices with those of conventional development approaches. Traditional approaches to stormwater management typically involve hard infrastructure, such as curbs, gutters, and piping. LID-based designs, in contrast, are designed to use natural drainage features or engineered swales and vegetated contours for runoff conveyance and treatment. In terms of costs, LID techniques can reduce the amount of materials needed for paving roads and driveways and for installing curbs and gutters. Other LID techniques can eliminate or reduce the need for curbs and gutters, thereby reducing infrastructure costs. Also, by infiltrating or evaporating runoff, LID techniques can reduce the size and cost of flood-control structures. Note that in some circumstances LID techniques might result in higher costs because of more expensive plant material, site preparation, soil amendments, underdrains and connections to municipal stormwater systems, as well as increased project management costs. Other considerations include land required to implement a management practice and differences in maintenance requirements. Finally, in some circumstances LID practices can offset the costs associated with regulatory requirements for stormwater control.

FINDINGS

Table 1. Cost Comparisons Between Conventional and LID Approaches

Project[a]	Conventional Development Cost	LID Cost	Cost Difference[b]	Percent Difference[b]
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	-$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creek[c]	$12,510	$9,099	$3,411	27%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

[a] Some of the case study results do not lend themselves to display in the format of this table (Central Park Commercial Redesigns, Crown Street, Poplar Street Apartments, Prairie Crossing, Portland Downspout Disconnection, and Toronto Green Roofs). [b] Negative values denote increased cost for the LID design over conventional development costs. [c] Mill Creek costs are reported on a per-lot basis.

Seventeen case studies were evaluated for this report. In general, the case studies demonstrated that LID practices can reduce project costs and improve environmental performance. Although not all the benefits of the projects highlighted in the case studies were monetized, with a few exceptions, LID practices were shown to be both fiscally and environmentally beneficial to communities. In a few case studies, initial project costs were higher than those for conventional designs; in most cases, however, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs. (Table 1)

A rain garden manages runoff from impervious surfaces such as roofs and paved areas.

In all cases, LID provided other benefits that were not monetized and factored into the project bottom line. These benefits include improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased total number of units developed, increased marketing potential, and faster sales. The case studies also provided other environmental benefits such as reduced runoff volumes and pollutant loadings to downstream waters, and reduced incidences of combined sewer overflows.

CONCLUSIONS

This report summarizes 17 case studies of developments that include LID practices and concludes that applying LID techniques can reduce project costs and improve environmental performance. In most cases, LID practices were shown to be both fiscally and environmentally beneficial communities. In a few cases, LID project costs were higher than those for conventional stormwater management projects. However, in the

APPENDIX D

Drainage Covenant

DRAINAGE ACCEPTANCE COVENANT

The Grantor, ________________________

___ (1) husband and wife,
___ (2) a married man,
___ (3) a single man,
___ (4) a single woman, or
___ (5) a _________________ corporation
___ (6) other, described as ______________________

Whose address is _________________________________, as owner of property described or as shown on the attached map as Exhibit A, agrees to accept the storm water runoff emanating from the property described or as shown on the attached map as Exhibit B, as provided by drainage plans dated ___________ and filed with the City of Battle Creek Departments of Public Works and Planning. The undersigned, with full knowledge of the alteration in drainage patters from preexisting conditions as provided by said drainage plans agrees for:

___ (1) themselves;
___ (2) him/herself; or
___ (3) itself,

Their/his/her/its heirs, successors and assigns, to indemnify, defend and save harmless the Approval Entity, its agents, officers and employees from and against any and all liability, expense, including defense costs and legal fees, and claim for damages of any nature whatsoever, including but not limited to bodily injury, death, personal injury, or property damage, arising from or connected with storm water runoff due to the alteration in drainage patterns described herein.

WITNESS:	GRANTOR(S):
________________________	______________________________
________________________	______________________________

STATE OF MICHIGAN)
) ss
COUNTY OF CALHOUN)

On this ____ day of __________________, __________, before me a notary public in and for said County personally appeared ______________________, the (title) ________________ of the corporation herein named, or the individual(s) herein named, to me known to be the person(s) described in and who executed the within Drainage Covenant and who acknowledged the execution thereof to be their/his/her/its free act and deed.

____
Notary Public
Acting in ______________ County, Michigan
My Commission Expires: ________________

This instrument drafted by:

Clyde J. Robinson, Esquire
P.O. Box 1717
Battle Creek, MI 49016-1717
(269) 966-3385

APPENDIX E

Site Plan Review Checklist

City of Battle Creek
Engineering Department
Drainage and Storm Water Management
Site Development Review Checklist

TO: ____________________________________
____
____
____
ATTN: ____________________________________

PAGE 1 OF 2
DATE

REVIEW OF HYDROLOGY STUDY
"_______________________ CHECK"

ADDRESS_____________________

____

TRANSMITTAL

DATE_____________

USGS

QUAD._____________________

Your hydrology study has been reviewed and is disapproved. Make corrections as shown on the returned hydrology study with associated plans as noted below. Resubmit these sheets with check print and two (2) revised sets of the hydrology study for further consideration. Additional changes may be required as determined by further review.

<u>DRAINAGE MAP CONTENTS</u>:

(____) The on-site drainage map must be of a scale not greater than 1" = 50', with elevation contours at 2 foot or less intervals.
(____) The off-site drainage map must be of a scale of not less than 1" = 1000'.
(____) Provide the civil engineer's signature, stamp and expiration date.
(____) Provide a location map at a scale not greater than 1" = 200'.
(____) Provide a North Arrow and scale.
(____) Provide a table showing the hydrologic data used to calculate the design rate of flow (Q). (i.e. storm frequency, rainfall zone, soil type, DPA zone, burn factor, bulking factor, percent impervious, etc.)
(____) Clearly show proposed and existing drainage patterns.
(____) Show and label proposed and existing drainage devices and storm drain improvements identified by number or name. Indicate the Design Q and tributary area for each existing drain.
(____) Show and label street locations, names, slopes, and provide typical sections.
(____) Provide adequate topography to support the area boundary determinations.
(____) Show and label boundaries and acreages for each sub-area. Boundaries of sub-areas should be distinctly outlined with color.
(____) Clearly indicate Q's and summation of areas at locations where flows leave the site for conditions before and after development.
(____) Show and label main line design Q's and Q's for each sub-area. Sub-area Q's should be prorated to provide design Q's for all inlets and structures.
(____) Show and label summation of areas at every junction and at the outlet.

DRAINAGE MAP COMMENTS (CONTINUED)

(____) Show and label time of concentration (tc) for each sub-area.

(____) Provide drainage area and Q tributary to downdrains which discharge to streets across lot pads.

CALCULATIONS COMMENTS:

(____) A pre-development hydrology study and a post-development hydrology study will be required when offsite drainage will occur (See flow chart in Figure 1.1-1 for details).

(____) Q calculations must be done in accordance with criteria presented in the Technical Reference Manual.

(____) Time of concentration calculations shall be provided.

(____) A catch basin or inlet study must be included and the Tc for each sub-area must be calculated to determine the peak flowrate.

(____) The minimum Tc that must be used is 5 minutes.

(____) Submit soils information in the form of borings and logs used in calculating saturated infiltration rates and dewatering rates. Verify soil field conditions for saturated infiltration rates and dewatering rates. Consult the current Michigan Department of Environmental Quality, Stormwater Management Guidebook http://www.deq.state.mi.us/documents/deq-lwm-nfip-SMGMastr.pdf. *(Care should be taken during construction to prevent soil compaction, which can alter calculated saturated infiltration rates and dewatering rates.)*

(____) OTHER COMMENTS:

APPENDIX F

Stormwater Maintenance Agreement

(Entity)

Storm Water Management
Maintenance Agreement

[Entity]

THIS AGREEMENT is made this day of _____ , 20__ , by and between the City of Battle Creek, a Michigan municipal corporation, 10 N. Division St., Battle Creek, MI 49014, hereinafter "City" and ____a [type of entity]___ with principal offices located ____, hereinafter "Responsible Party" by virtue of _________________, proof of which is attached hereto as Exhibit A.

Responsible Party for the property described below, in accordance with City of Battle Creek City Ordinance 1048 and all regulations adopted thereby, agrees to install and maintain storm water management system(s) on the subject property in accordance with approved plans and conditions. The Owner further agrees to the terms stated in this document to ensure that the storm water management system continue serving the intended function in perpetuity. This Agreement includes the following exhibits:

Exhibit A: Legal document required by 1048.16 of Battle Creek City Ordinance, or the Liber and Page number of the recorded document showing that the individual is the Responsible Party and has the authority for the construction and maintenance of the storm water management system on the real estate identified in Exhibit B. The legal document is defined as a Deed, Master Deed, Property Owners Association Charter or other evidence of authority.

Exhibit B: Legal description of the real estate for which this Agreement applies ("Property").

Exhibit C: Map(s) showing a location of the Property and an accurate location of each component of the storm water management system affected by this Agreement.

Exhibit D: Operation and Maintenance Plan showing the activities and schedule required to operate and maintain the permitted facilities otherwise known as the storm water management system.

Through this Agreement, the Responsible Party hereby subjects the Property to the following covenants, conditions, and restrictions:

1. The Responsible Party, at its expense, shall secure from any affected owners of land all easements, drainage acceptance covenants, and releases of rights-of-way necessary for utilization of the storm water system identified in Exhibit C and shall record them with the Calhoun County Register of Deeds. These easements and releases of rights-of-way shall not be altered, amended, vacated, released or abandoned without prior written approval of the City of Battle Creek.

2. The Responsible Party shall be solely responsible for the installation, maintenance and repair of the storm water management system, drainage easements, and associated landscaping identified in Exhibit C in accordance with the Maintenance Plan (Exhibit D).

3. No alterations or changes to the storm water management system identified in Exhibit C shall be permitted unless they are deemed to comply with this Agreement and are approved in writing by the City of Battle Creek.

4. The construction and performance of storm water management system need to be verified by the Responsible Party's licensed professional engineer. Documentation of the verification is required to obtain an occupancy permit.

5. The Responsible Party shall retain the services of a qualified inspector to ensure the maintenance of the storm water management system identified in Exhibit C in accordance with the Maintenance Plan (Exhibit D).

6. The Responsible Party shall keep records (logs, invoices, reports, data, etc.) of inspections, maintenance, and repair of the storm water management system and drainage easements identified in Exhibit C in accordance with the Maintenance Plan (Exhibit D) and provide the same to the City upon request.

7. The City of Battle Creek or its designee is authorized to, but not obligated to, access the property as necessary to conduct inspections of the storm water management system including drainage easements to ascertain compliance with the intent of this Agreement and the activities prescribed in Exhibit D. Upon written notification by the City of Battle Creek or their designee of required maintenance or repairs, the Responsible Party shall complete the specified maintenance or repairs within a reasonable time frame determined by the City of Battle Creek. The Responsible Party shall be liable for the failure to undertake any maintenance or repairs so that the public health, safety, and welfare shall not be endangered.

8. If the Responsible Party does not keep the storm water management system in reasonable order and condition, or complete maintenance activities in accordance with the Plan contained in Exhibit D, or the reporting or the required maintenance or repairs under 6 above within the specified time frames, the City of Battle Creek is authorized, but not required, to perform inspections, maintenance, or repairs, in order to preserve the intended functions of the system and prevent the system from becoming a threat to public health, safety, general welfare or the environment. In the case of an emergency, as determined by the City of Battle Creek, no notice shall be required prior to the City of Battle Creek performing emergency maintenance or repairs. In addition to any other remedy provided for by law, the City of Battle Creek may levy the costs and expenses of such inspections, maintenance, or repairs, plus a ten percent (10%) administrative fee against the Responsible Party. The City of Battle Creek at the time of entering upon said storm water management system for the purpose of maintenance or repair may file a notice of lien in the office of the Calhoun County Register of Deeds

upon the property affected by the lien. If said costs and expenses are not paid by the Responsible Party, the City of Battle Creek may pursue the collection of same through appropriate court actions and in such a case, the Responsible Party shall pay in addition to said costs and expenses all costs of litigation, including attorney fees.

9. The Responsible Party hereby conveys to the City of Battle Creek an easement over, on and in the property described in Exhibit B for the purpose of access to the storm water management system for the inspection, maintenance and repair thereof, should the Responsible Party fail to properly inspect, maintain and repair the system.

10. The Responsible Party agrees that this Agreement shall be recorded and that the land described in Exhibit "B" shall be subject to the covenants and obligations contained herein, and this agreement shall bind all current and future owners of the property.

11. The Responsible Party agrees in the event that the Property is sold, transferred, or leased to provide information to the new owner, operator, or lessee regarding proper inspection, maintenance and repair of the storm water management system. The information shall accompany the first deed transfer and include Exhibits C and D and this Agreement. The transfer of this information shall also be required with any subsequent sale, transfer or lease of the Property.

12. The Responsible Party agrees that the rights, obligations and responsibilities hereunder shall commence upon execution of the Agreement.

13. The parties whose signatures appear below hereby represent and warrant that they have the authority and capacity to sign this agreement and bind the respective parties hereto.

14. The Responsible Party, its agents, representatives, successors and assigns shall defend, indemnify and hold the City of Battle Creek harmless from and against any claims, demands, actions, damages, injuries, costs or expenses of any nature whatsoever, hereinafter "Claims", fixed or contingent, known or unknown, arising out of or in any way connected with the design, construction, use, maintenance, repair or operation (or omissions in such regard) of the storm drainage system referred to in the plan as Exhibit "D" hereto, appurtenances, connections and attachments thereto which are the subject of this Agreement. This indemnity and hold harmless shall include any costs, expenses and attorney fees incurred by the City of Battle Creek in connection with such Claims or the enforcement of this Agreement.

IN WITNESS WHEREOF, the Responsible Party and City of Battle Creek have executed this Agreement on the day and year first above written.

Responsible Party

WITNESSES:

____

___________________________________ By: ____

___________________________________ Its: ____

The foregoing instrument was acknowledged before me on this____________ day of ________________, 20 ___, by____, the ________________________ of ______________________.

____
Notary Public
__________________________ County of Michigan
My Commission Expires On:

City of Battle Creek

WITNESSES:

___________________________________ By: ____

___________________________________ Its: City Manager

The foregoing instrument was acknowledged before me on this____________ day of ________________, 20 ___, by ____, the ________________________ of ______________________.

____
Notary Public
__________________________ County of Michigan

My Commission Expires On:

INSTRUMENT DRAFTED BY: Eileen W. Wicklund (P41373) Battle Creek City Attorney 10 N. Division St. Battle Creek, MI 49014	WHEN RECORDED RETURN TO: Eileen W. Wicklund

Exhibit A

Deed, Master Deed, Property Owners Association Charter or other evidence of authority.

Exhibit B – Legal Description **(Sample)**

The following description and reduced copy map identifies the land parcel(s) affected by this Agreement.

[Note: *An example legal description is shown below. This exhibit must be customized for each site, including the minimum elements shown. It must include a reference to a Subdivision Plat, Certified Survey number, or Condominium Plat, and a map to illustrate the affected parcel(s)*.]

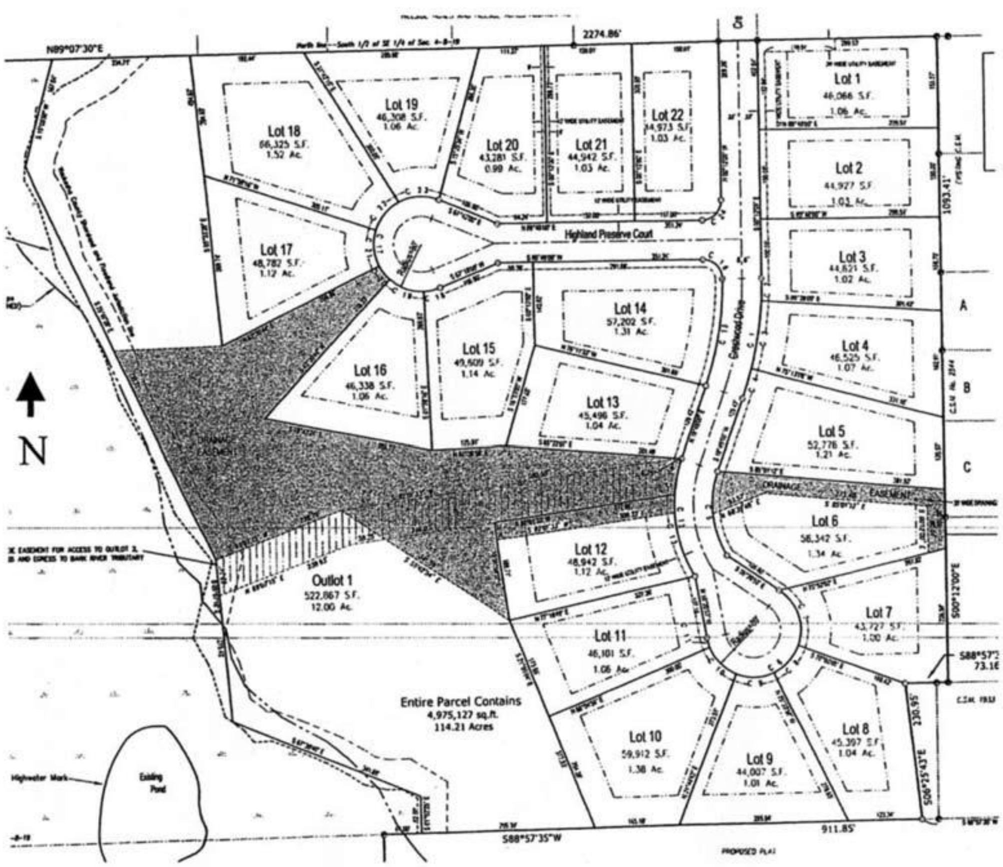
Project Identifier: Huron Preserve Subdivision

Acres: 40

Date of Recording: October 22, 2006

Map Produced by: ABC Engineering, P.O. Box 20, Green Oak Twp., MI

Legal Description: Lots 1 through 22 of Huron Preserve Subdivision, located in the Southwest Quarter (SW1/4) of Section 4, Township 8N, Range 19E (Green oak Township) Livingston County, Michigan. [If no land division is involved, enter legal description as described on the property title here.]



Drainage Easement Restrictions: Shaded area on map indicates a drainage easement for storm water collection, conveyance, and treatment. No buildings or other structures are allowed in these areas. No grading or filling is allowed that may interrupt storm water flows in any way. See Exhibit C for specific maintenance requirements for storm water management system within this area. See subdivision plat for details on location. *Huron Preserve Subdivision*

Exhibit C –Map **(Sample)**

Storm Water Management System Covered by this Agreement

[*An example map and the minimum elements that must accompany the map are shown below. This exhibit must be customized for each site. Map scale must be sufficiently large enough to show necessary details*.]

The storm water management system covered by this agreement are depicted in the reduced copy of a portion of the construction plans, as shown below. The system includes a wet detention basin, two forebays, two grass swales (conveying storm water to the forebays) and all associated pipes, earthen berms, rock chutes, and other components of these system. All of the noted storm water management systems are located within a drainage easement in Outlot 1 of the subdivision plat as noted in Exhibit B.

Subdivision Name: Huron Preserve Subdivision

Storm Water System: Wet Detention Basin #1, forebays (2), grass swales (2)

Location of System: All that part of Outlot 1, bounded and described in Figure G.1: [If no land division is involved, enter a metes and bounds description of the easement area.]

Titleholders of Outlot 1: Each Owner of Lots 1 through 22 shall have equal (1/22) undividable interest in Outlot 1 [For privately owned storm water management system, the titleholder(s) must include all new parcels that drain to the storm water management practice.]

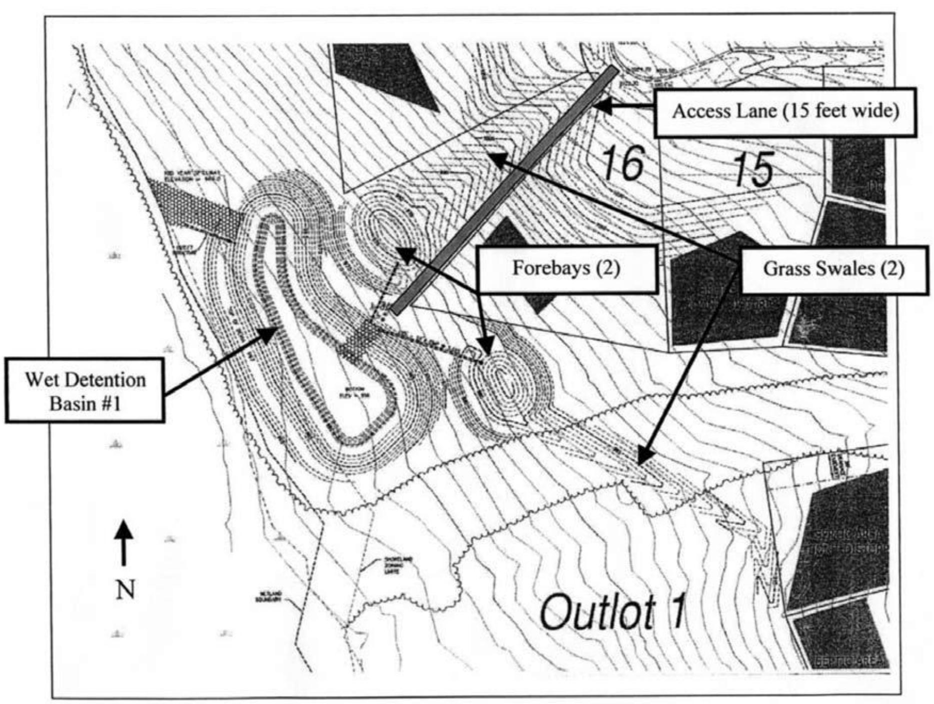


Exhibit D – Storm Water Practice Maintenance Plan (Sample)

This exhibit explains the basic function of each of the storm water system listed in Exhibit C and provides the minimum specific maintenance activities and frequencies for each practice. The maintenance identified by the Owner should follow the maintenance activities listed in this manual, if applicable. Vehicle access to the storm water system should be shown in Exhibit C. Any failure of a storm water practice that is caused by lack of maintenance will subject the Responsible Party to enforcement of the provisions listed in the Agreement by the City of Battle Creek.

The exhibit must be customized for each site. The minimum elements of this exhibit include: a description of the drainage area and the installed storm water management system, a description of the specific maintenance activities for each practice which should include in addition to specific actions:

- Employee training and duties,
- Routine service requirements,
- Operating, inspection and maintenance schedules, and
- Detailed construction drawings showing all critical components and their elevations.
- Keep records (logs, invoices, reports, data, etc.) of inspections, maintenance, and repair of the storm water management system and drainage easements identified in Exhibit B

References

Southeast Michigan Council of Governments (SEMCOG), *LID Manual for Michigan*

<u>APPENDIX G</u>

Stormwater Maintenance Agreement

(Individual)

Storm Water Management

Maintenance Agreement

[Individual]

THIS AGREEMENT is made this day of _____ , 20__ , by and between the City of Battle Creek, a Michigan municipal corporation, 10 N. Division St., Battle Creek, MI 49014, hereinafter "City" and ______________________________________, whose address is ____, hereinafter "Responsible Party" by virtue of ___________, proof of which is attached hereto as Exhibit A.

Responsible Party for the property described below, in accordance with City of Battle Creek Ordinance 1048 and all regulations adopted thereby, agrees to install and a maintain storm water management system(s) on the subject property in accordance with approved plans and conditions. The Owner further agrees to the terms stated in this document to ensure that the storm water management system continue serving the intended function in perpetuity. This Agreement includes the following exhibits:

Exhibit A: Legal document required by 1048.16 of Battle Creek City Ordinance, or the Liber and Page number of the recorded document showing that the individual is the Responsible Party and has the authority for the construction and maintenance of the storm water management system on the real estate identified in Exhibit B. The legal document is defined as a Deed, Master Deed, Property Owners Association Charter or other evidence of authority.

Exhibit B: Legal description of the real estate to which this Agreement applies ("Property").

Exhibit C: Map(s) showing a location of the Property and an accurate location of each component of the storm water management system affected by this Agreement.

Exhibit D: Operation and Maintenance Plan showing the activities and schedule required to operate and maintain the permitted facilities otherwise known as the storm water management system.

Through this Agreement, the Responsible Party hereby subjects himself/herself and the Property to the following covenants, conditions, and restrictions:

15. The Responsible Party, at its expense, shall secure from any affected owners of land all easements, drainage acceptance covenants, and releases of rights-of-way necessary for utilization of the storm water system identified in Exhibit C and shall record them with the Calhoun County Register of Deeds. These easements and releases of rights-of-way shall not be altered, amended, vacated, released or abandoned without prior written approval of the City of Battle Creek.

16. The Responsible Party shall be solely responsible for the installation, maintenance and repair of the storm water management system, drainage easements, and associated landscaping identified in Exhibit C in accordance with the Maintenance Plan (Exhibit D).

17. No alterations or changes to the storm water management system identified in Exhibit C shall be permitted unless they are deemed to comply with this Agreement and are approved in writing by the City of Battle Creek.

18. The construction and performance of storm water management system need to be verified by the Responsible Party's licensed professional engineer. Documentation of the verification is required to obtain an occupancy permit.

19. The Responsible Party shall retain the services of a qualified inspector to ensure the maintenance of the storm water management system identified in Exhibit C in accordance with the Maintenance Plan (Exhibit D).

20. The Responsible Party shall keep records (logs, invoices, reports, data, etc.) of inspections, maintenance, and repair of the storm water management system and drainage easements identified in Exhibit C in accordance with the Maintenance Plan (Exhibit D) and provide the same to the City upon request.

21. The City of Battle Creek or its designee is authorized to, but not obligated to, access the property as necessary to conduct inspections of the storm water management system including drainage easements to ascertain compliance with the intent of this Agreement and the activities prescribed in Exhibit D. Upon written notification by the City of Battle Creek or their designee of required maintenance or repairs, the Responsible Party shall complete the specified maintenance or repairs within a reasonable time frame determined by the City of Battle Creek. The Responsible Party shall be liable for the failure to undertake any maintenance or repairs so that the public health, safety, and welfare shall not be endangered.

22. If the Responsible Party does not keep the storm water management system in reasonable order and condition, or complete maintenance activities in accordance with the Plan contained in Exhibit D, or the reporting required, or the required maintenance, or repairs under 6 above within the specified time frames, the City of Battle Creek is authorized, but not required, to perform inspections, maintenance, or repairs, in order to preserve the intended functions of the system and prevent the system from becoming a threat to public health, safety, general welfare or the environment. In the case of an emergency, as determined by the City of Battle Creek, no notice shall be required prior to the City of Battle Creek performing emergency maintenance or repairs. In addition to any other remedy provided for by law, the City of Battle Creek may levy the costs and expenses of such inspections, maintenance, or repairs, plus a ten percent (10%) administrative fee against the Responsible Party. The City of Battle Creek at the time of entering upon said storm water management system for the purpose of maintenance or repair may file a notice of lien in the office of the Calhoun County Register of Deeds upon the property affected by the lien. If said costs and expenses are not paid by the Responsible Party, the City of Battle Creek may pursue the collection of same through appropriate court actions and in such a case, the Responsible Party shall pay in addition to said costs and expenses all costs of litigation, including attorney fees.

23. The Responsible Party hereby conveys to the City of Battle Creek an easement over, on and in the property described in Exhibit B for the purpose of access to the storm water management system for the inspection, maintenance and repair thereof, should the Responsible Party fail to properly inspect, maintain and repair the system.

24. The Responsible Party agrees that this Agreement shall be recorded and that the land described in Exhibit "B" shall be subject to the covenants and obligations contained herein, and this agreement shall bind all current and future owners of the property.

25. The Responsible Party agrees in the event that the Property is sold, transferred, or leased to provide information to the new owner, operator, or lessee regarding proper inspection, maintenance and repair of the storm water management system. The information shall accompany the first deed transfer and include Exhibits C and D and this Agreement. The transfer of this information shall also be required with any subsequent sale, transfer or lease of the Property.

26. The Responsible Party agrees that the rights, obligations and responsibilities hereunder shall commence upon execution of the Agreement.

27. The parties whose signatures appear below hereby represent and warrant that they have the authority and capacity to sign this agreement and bind the respective parties hereto.

28. The Responsible Party, its agents, representatives, successors and assigns shall defend, indemnify and hold the City of Battle Creek harmless from and against any claims, demands, actions, damages, injuries, costs or expenses of any nature whatsoever, hereinafter "Claims", fixed or contingent, known or unknown, arising out of or in any way connected with the design, construction, use, maintenance, repair or operation (or omissions in such regard) of the storm drainage system referred to in the plan as Exhibit "D" hereto, appurtenances, connections and attachments thereto which are the subject of this Agreement. This indemnity and hold harmless shall include any costs, expenses and attorney fees incurred by the City of Battle Creek in connection with such Claims or the enforcement of this Agreement.

IN WITNESS WHEREOF, the Responsible Party and City of Battle Creek have executed this Agreement to be effective on the day and year first above written.

Responsible Party

WITNESSES:

____

______________________________ By: ____

______________________________ Its: ____

The foregoing instrument was acknowledged before me on this___________ day of _______________, 20 ___, by____________________________________, the ______________________ of ____________________.

____
Notary Public
________________________ County of Michigan
My Commission Expires On:

City of Battle Creek

WITNESSES:

______________________________ By: ____

______________________________ Its: City Manager

The foregoing instrument was acknowledged before me on this___________ day of _______________, 20 ___, by ____________________________________, the ______________________ of ____________________.

____
Notary Public
________________________ County of Michigan

My Commission Expires On:

INSTRUMENT DRAFTED BY: Eileen W. Wicklund (P41373) Battle Creek City Attorney 10 N. Division St. Battle Creek, MI 49014	WHEN RECORDED RETURN TO: Eileen W. Wicklund

Exhibit A

Deed, Master Deed, Property Owners Association Charter or other evidence of authority.

Exhibit B – Legal Description **(Sample)**

The following description and reduced copy map identifies the land parcel(s) affected by this Agreement.

[Note: *An example legal description is shown below. This exhibit must be customized for each site, including the minimum elements shown. It must include a reference to a Subdivision Plat, Certified Survey number, or Condominium Plat, and a map to illustrate the affected parcel(s).*]

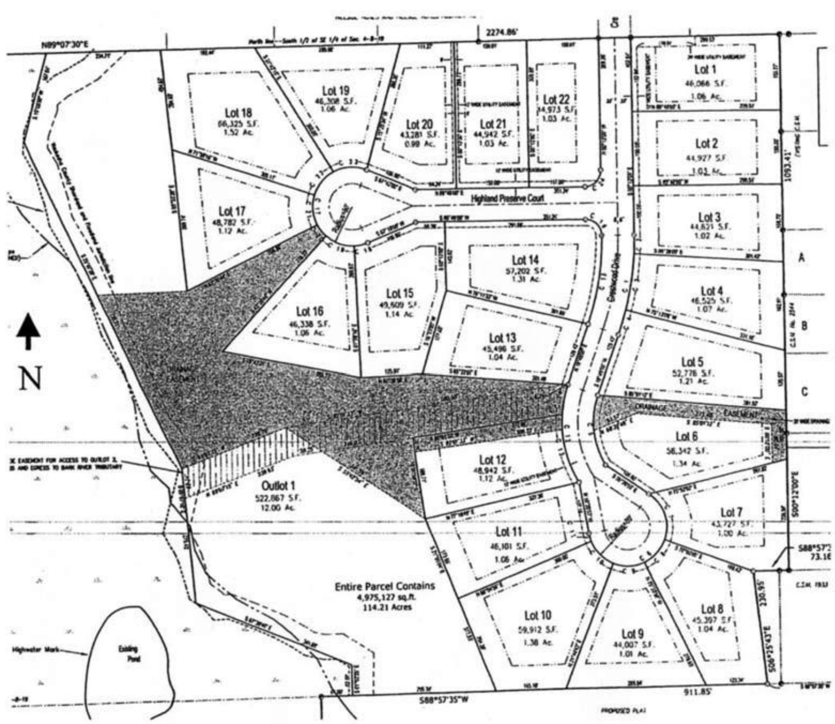
Project Identifier: Huron Preserve Subdivision

Acres: 40

Date of Recording: October 22, 2006

Map Produced by: ABC Engineering, P.O. Box 20, Green Oak Twp., MI

Legal Description: Lots 1 through 22 of Huron Preserve Subdivision, located in the Southwest Quarter (SW1/4) of Section 4, Township 8N, Range 19E (Green oak Township) Livingston County, Michigan. [If no land division is involved, enter legal description as described on the property title here.]



Drainage Easement Restrictions: Shaded area on map indicates a drainage easement for storm water collection, conveyance, and treatment. No buildings or other structures are allowed in these areas. No grading or filling is allowed that may interrupt storm water flows in any way. See Exhibit C for specific maintenance requirements for storm water management system within this area. See subdivision plat for details on location. *Huron Preserve Subdivision*

Exhibit C –Map **(Sample)**

Storm Water Management System Covered by this Agreement

[*An example map and the minimum elements that must accompany the map are shown below. This exhibit must be customized for each site. Map scale must be sufficiently large enough to show necessary details*.]

The storm water management system covered by this agreement are depicted in the reduced copy of a portion of the construction plans, as shown below. The system includes a wet detention basin, two forebays, two grass swales (conveying storm water to the forebays) and all associated pipes, earthen berms, rock chutes, and other components of these system. All of the noted storm water management systems are located within a drainage easement in Outlot 1 of the subdivision plat as noted in Exhibit B.

Subdivision Name: Huron Preserve Subdivision

Storm Water System: Wet Detention Basin #1, forebays (2), grass swales (2)

Location of System: All that part of Outlot 1, bounded and described in Figure G.1: [If no land division is involved, enter a metes and bounds description of the easement area.]

Titleholders of Outlot 1: Each Owner of Lots 1 through 22 shall have equal (1/22) undividable interest in Outlot 1 [For privately owned storm water management system, the titleholder(s) must include all new parcels that drain to the storm water management practice.]

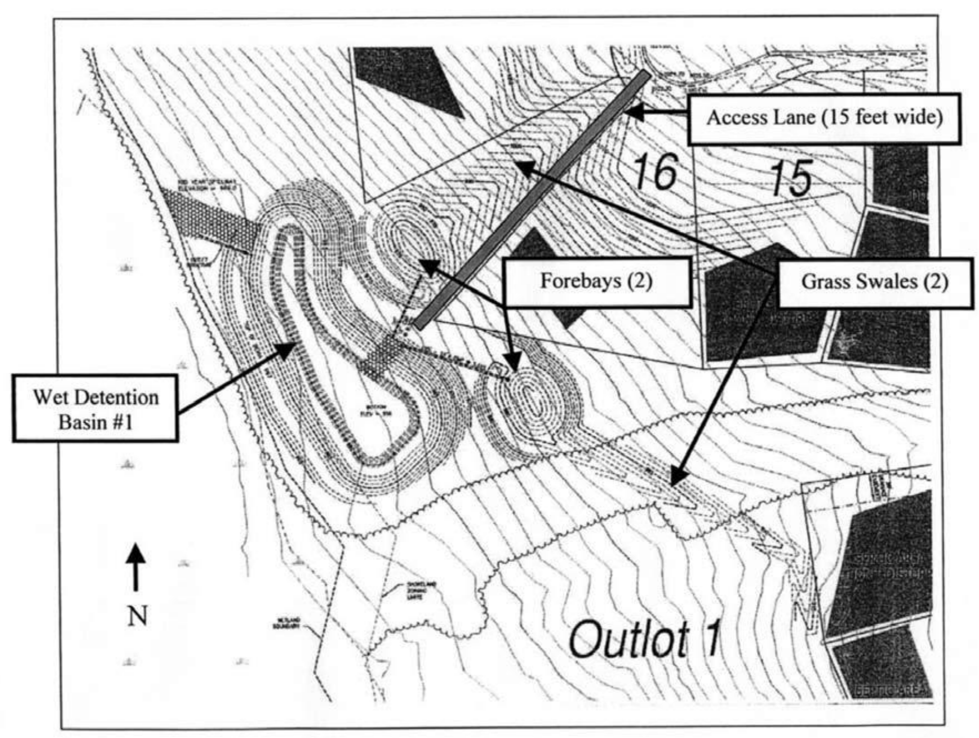


Exhibit D – Storm Water Practice Maintenance Plan (Sample)

This exhibit explains the basic function of each of the storm water system listed in Exhibit C and provides the minimum specific maintenance activities and frequencies for each practice. The maintenance identified by the Owner should follow the maintenance activities listed in this manual, if applicable. Vehicle access to the storm water system should be shown in Exhibit C. Any failure of a storm water practice that is caused by lack of maintenance will subject the Responsible Party to enforcement of the provisions listed in the Agreement by the City of Battle Creek.

The exhibit must be customized for each site. The minimum elements of this exhibit include: a description of the drainage area and the installed storm water management system, a description of the specific maintenance activities for each practice which should include in addition to specific actions:

- Employee training and duties,
- Routine service requirements,
- Operating, inspection and maintenance schedules, and
- Detailed construction drawings showing all critical components and their elevations.
- Keep records (logs, invoices, reports, data, etc.) of inspections, maintenance, and repair of the storm water management system and drainage easements identified in Exhibit B

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